Science Teaching

by Hoff

Secondary-school

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A TEXTBOOK ON HOW TO TEACH SCIENCE IN THE JUNIOR AND SENIOR HIGH SCHOOL

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REDLANDS, CALIFORNIA

PHILADELPHIA · THE BLAKISTON COMPANY · TORONTO

1950

Reprinted, August 1950

Printed in the United States of America

To Elizabeth W. Hoff

A HELPFUL COMPANION

IN WORK AND PLAY

Preface

This book is a result of twelve years' experience as a teacher of science in the junior and senior high school and nine years in the area of training science teachers for the public secondary school. In assembling this material for a book on the teaching of science an attempt was made to meet a need for a text which contains an up-to-date summary of functional information as determined by experience and research.

On the undergraduate and graduate level, great economy has been achieved by the use of up-to-date texts which contain the more important information on the subject intended for study. The use of syllabi and lengthy reading lists often results in a great deal of duplicative reading and waste of time in procuring and waiting for reference books. A single text such as the present may be employed as the core or as basic reading material.

Beginning teachers must master to a functional degree one method of teaching which will carry them through until experience and further study enable them successfully to develop improved techniques. This book attempts to present in detail a plan for unit teaching and subsequently treats other plans more briefly.

The intention has been to give the science teacher guidance on the total area of teaching. Not only the problems met with in the science classroom, but responsibilities relative to guidance, administration, and contact with the community have been discussed. It is hoped that the reader, whether he is a beginning teacher or one of experience, may be helped toward a sound philosophy of science teaching and secure concrete suggestions which will make his teaching more satisfying and efficient.

Arthur G. Hoff

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The Mission of Science in Education

The science teacher occupies an important place in the total educational growth of the secondary school pupil. Adjustments to the problems which the human organism faces in a modern society are impossible to achieve unless pupils are given adaptive experiences in the area of science. The environment in which we live is predominantly colored by science and will become more so during the coming years. Our youth must be prepared to make adaptations which will result in successful living in a strenuous and complicated environment. The complex life into which civilization has been catapulted during the last century has been brought about largely by scientific developments. Scientific study, then, is a necessary part of the modern educational program. The science teacher must possess a deep conviction that the experiences which he is privileged to make available to his pupils are vital and will be functional in their contemporary and later life.

In order to achieve this faith and confidence in the worthwhileness of the area of science teaching, the teacher should be informed as to (1) the importance of utilizing the most efficient technique in guiding his pupils, (2) the background and history of science teaching coupled with a projection into the future, (3) the educational values of science teaching, and (4) the importance of the position which a science teacher holds in the life of secondary school pupils and the community. The important place which science teaching occupies in modern education has been achieved through long and persistent vigilance on the part of zealous students of science who envisaged the power of science to enrich life. The educational values of science are numerous and may be classified into practical, disciplinary, and cultural values. The science teacher has important responsibilities in interpreting the findings of science to his pupils and community and in emphasizing its constructive contributions to society.

1
Introduction

NEED FOR TECHNIQUES IN SCIENCE TEACHING

Specialized techniques are necessary to ensure efficient rendering of service by our professions and technical trades. Many of these methods of practice are a result of years of intensive evaluation and study, utilizing the outcome of research, critical observation, and trial and error. As knowledge has increased, techniques likewise have improved.

In the area of medicine, for example, clinical practice occupies an important place in the training of a medical practitioner before the M.D. degree is awarded and a license is granted for offering his services to the public. In the profession of law, techniques in court procedure make up a large part of the training which the young lawyer must have before he is admitted to the bar.

Likewise, in the profession of teaching, specialized and improved techniques are necessary in addition to the mastery of subject matter. There are certain principles and procedures which are applicable to the teaching of all subject areas, but efficient teaching of the individual subject fields necessitates specialized techniques which are peculiarly adapted to specific areas of instruction. In the field of science we find that the use of the laboratory, certain types of directed study, and source materials require methods of teaching which are different from those employed successfully in other subject areas.

In order to implement the present knowledge of educational psychology and the philosophies of education, knowledge of the subject is insufficient preparation for the important responsibility of teaching science. It is necessary to have training in the best procedures which have been found to be efficient.

Factors Which Make Techniques Important. It has been realized that the changes taking place in the secondary school population during the last generation are the primary reason why improved methods of teaching are needed to serve these adoles-

cents. Practically the total population of secondary school age is attending school at the present time. Instead of being a select group of pupils whose primary objective in attending the secondary school is preparation for college and the professions, a large proportion of the present school population is composed of pupils of low ability. The range of ability has been greatly increased, extending from pupils having an I.Q. of less than 80 to those with an I.Q. of 140 or more. In large groups, caring for the individual needs of pupils with such diverse abilities and interests necessitates efficient techniques. Granting that bright pupils learn in spite of the teacher or method employed, we know that greater degrees of growth can be achieved by them if opportunities that challenge their best abilities are provided. Likewise, pupils in the lower ability areas can be guided toward greater achievements by means of scientifically conceived methods which are best suited to their capacities.

A second factor which points to the need for training in improved procedures in science teaching, and other areas as well, is the fact that teachers tend to teach as they have been taught, unless they have learned more appropriate methods during their training period.

The most recent methods of teaching which a college student or college graduate recalls are the methods employed by his professors in college. College methods are not likely to be successful in junior or senior high school, and much less likely to be successful in the elementary school. For this reason, prospective teachers must learn the special techniques which are suitable for the instruction of pupils on different levels in the public schools. Studies in the area of educational methods—especially in the field of science—fill several large volumes. The more significant of these studies should be selected and presented for the use of the future teacher.

Teachers of special subject matter indulge in a great deal of skepticism toward the methods and psychology of teaching any subject. The author has spent hours listening to derogatory discussions regarding the efficiency of modern teaching methods and psychology. It is true that many teachers who know little of the psychology of education and the special techniques in presenting

material for certain age levels are good teachers because they have developed a method of teaching which is suited to their personality and special abilities. Also, they have been sufficiently observing and critical of their own results to discover, through trial and error, the procedures by means of which they can teach successfully.

The author is reminded of a college professor of physical chemistry, under whom the subject was studied, who refused to permit his students to be ''spoiled'' by the psychologists and professors in the college of education of this great university. The professor, although not cognizant of it, taught his students a method of teaching along with teaching them physical chemistry. He was skilled in the technique of chalk-talking and diagramming; hence, he made his presentations very interesting and graphic so that the ideas could be easily grasped by his students. Naturally, his students would imitate this method of teaching, which would function quite successfully in the secondary school.

Unfortunately, there is a very small proportion of teachers of this type in our colleges. The prospective teacher, therefore, must spend a portion of his time in college in acquiring information and must have an opportunity to practice the tested and tried methods of imparting information and skills or of effecting growth in the learner.

What is the distinction between good and poor teaching? This may be made clear by stating what constitutes good teaching. Good teaching is efficient, and there is a high degree of academic, moral, and social achievement. This is accomplished through the use of the principles of learning and the principles of mental hygiene. For example: (1) human beings learn by doing; (2) interest motivates for greater learning; (3) learning is greater when the pupil is happy in his learning experiences; and (4) the recognition of and caring for individual differences is mandatory for efficient teaching. In poor teaching the preceding desirable characteristics generally are absent.

HISTORY OF SCIENCE TEACHING

Progress in the acceptance of science as a subject worthy of place in the educational program was very slow. A review of the historical development of science teaching reveals several forces

which effectively retarded the development of scientific study and teaching. Among these forces were (1) religious influences and (2) college entrance requirements.

Religious Influences. The atmosphere of the early colonial days was a strongly religious one. The primary purpose of many of the pioneer settlements was religious freedom and the dominant objective in education was to achieve this end. A majority of the writers and teachers of the period were clergymen; therefore, scientific information which did not conform to the religious beliefs was deliberately withheld.

Later, the teaching of the sciences, especially the biological area, was teaching accepted by religious leaders as a means of bringing the pupil closer to God, thereby increasing reverent awe of the Creator through the study of his works. The subjects included were natural history, zoology, astronomy, and geology. The authors of texts used facts from these sciences which tended to prove the Creator to be wise and benevolent, and to strengthen the student's belief in the supernatural ordering of natural events.

College Entrance Requirements. One of the major purposes of the early college was to prepare young men for the ministry, and the requirements for admission to the institutions of higher learning were limited to proficiency in Latin and Greek. Science was not accepted for college entrance until 1872 when Harvard added physics to the approved list of preparatory subjects.

Science Teaching Before 1872. Because dogma ruled the civilized world, Michelangelo and Leonardo da Vinci are remembered as artists although they were true scientists. Francis Bacon (1561–1626) fostered the beginnings of science in education when he proposed the inductive method. Comenius, Rousseau, Basedow, Pestalozzi, Froebel, and Herbart, who lived during the century and a half before 1850, contributed greatly to science education through object lessons in natural science.

The Latin grammar schools, first established in America at Boston in 1635, offered no instruction in science. It was not until Benjamin Franklin recognized the need for a practical education for those who were to enter occupations other than the professions and the clergy that science education was formally realized. With the establishment of the Philadelphia Academy by Franklin in

1751, and the subsequent growth in the number of such academies throughout the states, came a development in the teaching of science. Natural philosophy, which was largely physics in those days, chemistry, astronomy, and, to a small extent, zoology, botany, and geology were rather well established before 1850 when the academy was at the height of its development.

The present free public high school evolved from the academy, the main difference being the change from private financing and control to public sponsorship. The first high school was established in Boston in 1821, and was designated as the English High School. Momentum was given to the growth of the high schools when the courts of Michigan held, in 1874, that taxpayers had a right to establish high schools and tax themselves for their support. The historic incident was designated as the Kalamazoo Case, which is a milestone in American education.

Objectives. The purposes of early science teaching were primarily utilitarian, religious, and descriptive. The utilitarian objective is the only one which is predominant today, while the descriptive phase of science teaching is gradually waning, and the religious emphasis is nonexistent. The instructional materials were encyclopedic in character and very fragmentary as a result of the nonfunctional nature of the purposes.

Methods of Teaching. Lecture and discussion held a prominent part in the early teaching procedures because of the lack of printed materials. Later, in the period when books became more accessible, learning activities consisted mainly of assigned things to do and the hearing of memorized or learned assignments. There was no opportunity for enriched reading as in the schools today. The laboratory method was unknown and records of experimentation were inaccurate. Object lessons and specimens, if used at all, were a means of verifying information given in the texts. The early science teachers were cognizant of the need for demonstrative and illustrative materials which were used when study coincided with common experience, but when unfamiliar things were studied the absence of such materials made the learning largely memorization without understanding.

Period of College Domination (1870–1910). The example set by Harvard in accepting physics as a prerequisite for college

entrance in 1872 was rapidly followed by other institutions, and the honor extended to other science subjects. Because of the lack of standardization in the secondary schools, the college proceeded to dictate in detail the nature of science instruction which would be accepted by them. Some of the requirements were that the science must be taught by a college-trained teacher; a definite minimum amount of time must be provided for its study per week for a definite length of time; the textbook must be accepted or designated by the college; a certain amount of laboratory work must be done; and evidence of such work must be presented in the form of a written record.

Secondary school science courses were largely abbreviated college courses because of the lack of ability on the part of secondary school teachers to formulate satisfactory science instructional materials. It then became necessary for colleges to prescribe definite courses of study to be pursued, and they included them in textbooks constructed by members of their own science departments. It is apparent that these instructional materials would be dominated by the college point of view. This college influence had both beneficial and harmful effects. The beneficial results were that college recognition increased the importance of science and greater standardization was achieved on a higher level. A detriment was inherent in textbooks unsuited to secondary school pupils and this forced to the fore the college preparatory function of the secondary school.

Objectives. During this period, the religious objective gradually disappeared, the disciplinary value came into full acceptance as of primary importance, and the informational and utilitarian aims maintained a prominent place. The doctrine of formal discipline achieved its maximum acceptance, and the paramount objective of science teaching was to develop the faculties of reasoning, observation, concentration, sensory training, and the like. The influence of faculty psychology and formal discipline resulted in a formalized and systematized form of education designed to train the universally possessed faculties while paying little attention to individual interests and abilities.

Methods of Teaching. Laboratory instruction became very popular during this period. It fulfilled the earlier felt need of

instruction through firsthand observation and manipulation, and it was believed that much of the disciplinary value of science study was achieved in the laboratory. In the biological sciences, the laboratory work consisted of the study of types based upon plant and animal morphology. Each type was studied intensively with the aid of minute directions and a study of the text and references. The laboratory manual was developed to aid in the efficiency of laboratory instruction, and elaborate and complete laboratories were provided for secondary schools as well as for colleges.

During the latter part of this period, the beginnings of a combined course in botany and zoology, called biology, were evident. These courses were in reality only separate short courses in botany, zoology, and human physiology crowded into a single year without an attempt at integration or correlation. The economic phase of living things was given increased emphasis in the high school courses, and the inductive method was stressed by presenting instructional materials in the form of problems.

Period of Reorganization (1910–). Many factors operated to bring about the period of reorganization which exists today and which apparently has not yet reached its maximum growth. Among these modifying forces may be listed (1) abandonment of the faculty psychology, (2) the junior high school movement, (3) rebellion against college domination of secondary school curricula, (4) increase in the secondary school population, and (5) findings of modern psychology.

Studies in the psychology of learning, in which Edward L. Thorndike pioneered, revealed the invalidity of the assumption that the human organism's mental behavior pattern was compartmentalized into several faculties or abilities, such as reasoning, memorization, and observation; that the behavior pattern could be trained by exercising these abilities; and that these abilities when developed would function in all life situations. Justification could no longer be made for abstract, meaningless, and laborious tasks which entirely too large a percentage of pupils failed to master. It became clearly evident that pupils needed to be taught more specific information, skills, attitudes, and interests which were functional in their daily living as children and adults. Modern education is making some progress toward achieving this end.

With the growth of the junior high school which developed as a result of the need for a revitalized curriculum in the upper elementary grades, came the development of science instruction that would help pupils interpret their environment. This science instruction took the form of general science which was to serve two primary purposes: (1) interpretation of the environment, and (2) exploration in the sciences.

General science had its beginning between 1910 and 1915, although a few schools were experimenting with functional and reorganized courses as early as 1900. By 1930, a majority of the schools of the nation were teaching general science.

Rebellion against college domination dates back to the year 1905 and has achieved increased impetus each year since that date. In many states the junior high school, including the ninth grade, has been freed from the dictates of college entrance requirements. The most recent organized effort to secure objective data through scientific experimentation is the study of the Progressive Education Association[1] which began in 1933. The study involved 30 secondary schools and several coöperating institutions of higher learning. Data are available over an eight-year period comprising a large group of youth who have passed through four years of secondary school without college domination and four years of college work. The results show conclusively that the subject matter studied in the secondary school bears no relationship to success in college; but that scholastic aptitude, habits of work, intellectual maturity, competent use of the mother tongue, and sense of personal and social responsibility are factors of validity. One major implication in this study is that the fact is established beyond question that the high school need not be controlled by the traditional content and procedures.

Increase in the secondary school population is the underlying cause for demands for a reorganized secondary school curriculum. During the last 40 years, the increase in pupils of high school age who are enrolled in high school has been from 6 per cent to above 65 per cent. In many communities, especially cities, nearly all pupils of high school age, who are physically and mentally able to succeed in the learning experiences, are enrolled. Since only 20

[1] Aikin, W. M.: "The Story of the Eight-Year Study," Chaps. V, VI, New York, Harper and Brothers, 1942.

per cent of the pupils who graduate from high school enter college, it is impossible for a college-dominated high school to minister to the needs of four-fifths of the high school population. As long as the majority of high schools in the nation have less than 100 pupils, it is obvious that they are unable to follow anything but a college preparatory program if they are bound to these requirements.

The findings of modern psychology reveal that a majority of the high school population is unable to make effective application and transfer of principles now learned in school. It is necessary, therefore, to make the transfers and applications as they are being studied. This can be done most effectively by relating the subject matter to the pupil's environment; that is, build learning experiences around problems vital to the life of the learner.

Learning Studies in Science Teaching. Learning studies in the area of science teaching have been made at an increasing rate since the first study published in 1910. Since that date, several hundred studies of varying comprehensiveness have been made by graduate students, teachers, and college professors. Summaries of selected studies completed in 1937 consume three large volumes which have been compiled by Francis D. Curtis.[2]

COMMITTEES AND COMMISSIONS

Commission on the Reorganization of Secondary Education. This commission was appointed by the National Education Association and, in its well-known report, "Cardinal Principles of Secondary Education,"[3] held that education should contribute to (1) health, (2) command of fundamental processes, (3) worthy home membership, (4) vocation, (5) citizenship, (6) worthy use of leisure, and (7) ethical character. In its bulletin published in 1920, entitled "Reorganization of Science in Secondary Schools,"[4] the Committee urged that the sciences be organized and taught

[2] Curtis, Francis D.: "A Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools," 1926; "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931; "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939.

[3] *Bull. U. S. Bur. Education,* No. 35, 1918.

[4] Report of the Committee on Standards for use in reorganization of secondary school curricula, *North Central Assoc. Quarterly, 1*: 428–444, 1927.

in such a manner that they would contribute to the Seven Cardinal Principles, except fundamental processes. A number of methods were suggested by which this could be effected, among them being the project method, which was at the height of its popularity at that time.

The National Society for the Study of Education in 1932 published a report, "A Program for Science Teaching,"[5] which has had considerable influence on science instruction. It emphasized the building of learning exercises and experiences around broad principles which are fundamental to the understanding of nature. An example is: "Matter cannot be created or destroyed but may be changed in form." These generalizations may constitute the theme for units ranging from kindergarten through the college, the difficulty of the interpretation being commensurate with grade levels in which it is presented.

The Commission on Secondary School Curriculum of the Progressive Education Association, in its publication, "Science in General Education," presents a scholarly criticism of present practices in science teaching and gives suggestions as to how science offerings in the secondary school should be adapted to the needs of adolescents. These needs are: (1) personal living, (2) immediate personal-social relationships, (3) social-civic relationships, (4) economic relationships, and (5) reflective thinking.[6]

THE PRESENT STATUS OF SCIENCE TEACHING

The most comprehensive survey on the present status of science teaching was made in 1932 by Wilbur Beauchamp,[7] who visited schools in 14 cities in different parts of the country and analyzed 58 courses of study in general science, 45 in biology, 27 in physics, and 30 in chemistry, all of which were less than 10 years old. This study revealed that at present science teaching is a conglomeration of the orthodox practices of the period of mental discipline (1880–

[5] National Society for the Study of Education, Thirty-first Yearbook, Part I, Bloomington, Ill., Public School Publishing Co., 1932.

[6] Thayer, V. T., *et al.*: "Science in General Education," New York, D. Appleton-Century Co., 1938.

[7] Instruction in science, *Bull. U. S. Bur. Education,* No. 17, 1932; "National Survey of Secondary Education," Monograph No. 22, U. S. Bur. Education.

1910) and newer practices of the two decades preceding the study. It combines the study of a systematic organization of facts, shows the importance of pure and applied science in modern life, and attempts to meet the needs of the individual in everyday life by imparting useful scientific information. The newer courses, general science and biology, are firmly established in the secondary school curriculum and keep almost—within five to seven years—abreast with modern thought in education. On the other hand, courses in physics and chemistry in the main cling to the aims of mental discipline with a few utilizing the newer practices.

Little or no general agreement was found in the stated objectives and in general the aims of science teaching were found to be somewhat in a state of confusion. This lack of unified purpose most likely is due to the shift in psychological theory. Extended time will be necessary to restore the definiteness of bases for a new approach. The organization of courses in applied science and an increasing emphasis on concrete applications of science to everyday life is a significant trend.

TRENDS IN SCIENCE TEACHING

The Yearbook Committee lists 12 significant trends regarding the learning activities and teaching procedures. These are stated as follows:[8]

1. A critical review and analysis of the investigations of teaching procedures already reported.
2. An attempt at refinement, better description, and definition of science demonstrations as teaching devices.
3. An attempt at redefinition, better limitation, and description of laboratory instruction, with attempts at evaluation of laboratory instruction as a means of producing certain definite outcomes in pupils.
4. A marked swing toward a unit organization of subject matter and instructional techniques in all high school sciences.
5. A critical review of existing science tests, accompanied by attempts to select and build tests to meet particular instructional needs.
6. A movement for the diagnosis of pupil difficulties in the learning of science materials.
7. A frank facing of the laboratory-instruction issue upon the basis of available apparatus and equipment now found in high schools.

[8] National Society for the Study of Education, Thirty-first Yearbook, *Op. cit.,* p. 269.

8. A revival of interest in simple, homely, and home-made laboratory and demonstration apparatus.

9. A beginning of experimental investigation of the value of visual aids, especially moving pictures, in instruction.

10. A continued development of the use of extensive reading for general instruction in science.

11. A continued interest in the possibilities of science clubs.

12. A general and spreading interest in the use of free and inexpensive supplementary material drawn into the school from outside commercial sources.

FUTURE DEVELOPMENTS

As evidence accumulates showing that the content of secondary subjects bears little relationship to success in college, and as organizations representing the welfare of youth increasingly demand freedom from college domination, the secondary school will be freed to minister to the needs of American adolescence. In the area of science teaching, this will mean more functional programs. The present specialized science subjects of chemistry and physics will be replaced by generalized science courses stressing the practical phases which are functional in daily living.

In view of the fact that approximately 80 per cent of high school graduates will receive no further general education it is evident that the general science and biology offered are inadequate as a preparation for living in the highly scientific environment of today. Chemistry and physics should be fused into a single course so as to permit a broadened science program including additional study in elementary geology, meteorology, and a broadened and functional study of health and consumer science. Under such a plan, science will be compulsory throughout the entire 12 grades of the public school system. Learning experiences will be adapted to the maturity and background of the pupils. Under a well-planned and coördinated science program through the 12 grades, the average graduate of our high schools should possess functional science knowledge equal to that of students who have completed the junior college at the present time. By the end of the sixth grade, pupils can achieve growth in science equivalent to that possessed by the average ninth-grade pupil after spending one year studying general science as taught today. Considerable science knowledge and understanding can be economically taught at lower grade levels than is now the practice.

The progress in educational procedures is very slow, as has been so clearly in evidence in this brief review of the history of science teaching. We cannot hope, therefore, to see a comprehensive science program in operation in a majority of school systems for two or three decades. The elementary school science program began to develop with concerted effort approximately 10 years ago and still has not achieved the status of universal practice.

STUDY QUESTIONS

1. What are two reasons for giving the prospective teacher training in the special techniques of teaching science?
2. Why are college methods not applicable to secondary school teaching?
3. What constitutes good teaching?
4. What forces retarded the progress of teaching?
5. Name three periods in the history of science teaching, and briefly describe what took place during each period.
6. What were the forces which precipitated the reorganization?
7. What are the objectives of junior high school science?
8. What evidence is there which justifies that secondary schools be independent from college domination?
9. How extensive are the learning studies in the teaching of science?
10. What committees have contributed to the reorganization of secondary education, and what did each contribute?
11. What is the present status of science teaching?
12. What are the aims for the future developments of science teaching?

ADDITIONAL PROBLEMS AND PROJECTS

1. Write a paper on the history of science teaching.
2. Make a detailed report on the work of one or more of the committees on reorganization of secondary education.

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2

The Educational Values of Science

In order for a teacher of science to be enthusiastic and effective in the dissemination of scientific knowledge, it is paramount that he be convinced that this information is vital in every person's life. It is indisputable that today science is the byword and that the scientific aspect of things is emphasized everywhere one goes.

PRACTICAL VALUES OF SCIENCE

One frequently hears a business man say that he is running his business scientifically, that is, his sales methods are based upon scientific information and his products are built and produced scientifically. Our environment to a great degree is influenced by science. The clothing we wear, the houses in which we live, the agricultural methods which produce our food and necessities, our automobiles, our telephones, our radios, the electrical appliances which are used in the home—all are based upon scientific information. Our environment would be entirely changed if it were not for our continual exposure to the results of the application of scientific principles.

Science has specific application in many of our life activities. For example, in the measurement of mental functions (in the science of education), science comes into operation with the application of the statistical method. Psychology is science applied for the purpose of securing information regarding the workings of the mind and it has made possible the separation and differentiation of human abilities, interests, and skills.

In the field of business, we find that science is applied to secure efficient management. It is applied to the assembled interpretation of statistics which are compiled regarding the business. Industry would still be an infant if it were not for science. Science has given us our methods of extracting the metals from their ores. The many varieties of steel would be unknown were it not for the applications of science. Without science, the refining of sugar would be

impracticable; the brewing and the distilling industries would still be in the beginning stages; cement would be unknown, and our thousands of miles of paved highways, concrete bridges, steel and cement fireproof buildings, and many other improvements would not yet be a reality. The electrical industry would be non-existent were it not for science. It is clear that without science most of our luxuries and comforts would be unknown.

In the field of medicine, science has contributed greatly, for medical practice did not progress appreciably until scientific principles were applied to the study of medical problems. Through science many life-saving preventives and cures have been developed. Among these are vaccines, serums and antitoxins for the prevention and control of diseases which for centuries had decimated the populations of the world. Through science, organic and inorganic drugs have become available for the treatment and cure of infectious diseases formerly considered inevitably fatal. The much dreaded disease, diabetes mellitus, which formerly proceeded to a lethal end within a limited time, has been brought under a measure of control through the discovery and production of insulin, the careful use of which enables the diabetic now to live a normal life to a mature age.

Science has given us the fundamental study of physiology and through its systematic application, understanding of the body functions is gradually extending. Inevitably, ways of living which are in harmony with the laws of nature are being discovered, and when normal functions become disordered, scientific investigation discovers a means by which to restore these chemical reactions to normal.

Science has helped in the reduction of human suffering through the development of different types of anesthetics for use in surgery, and sedatives and narcotics to relieve the pain and suffering which accompany diseases and injuries of the human mechanism.

Another field in which science has been active and effective is astronomy, which has helped us to understand the composition and the organization of the universe. It has been found that the earth is neither a significant part of the universe nor the center of it, as was believed by the early astrologers and wisemen. Rather, it is now known that the world is an insignificant portion of the uni-

verse, a mere speck among billions of particles many times larger than itself.

Science has helped us to understand the operation and behavior of the atmosphere which surrounds the earth. We have been able to forecast the types of air movements and temperatures which, in turn, determine the weather that is to come. In many cases this prediction is extended to more than a week in advance, and it achieves more than 95 per cent accuracy for 24 to 48 hours. This phase of science has augmented the tremendous development of aerial transportation, and has aided greatly in agriculture and land transportation. The dissemination of scientific knowledge has also effected a reduction of popular superstitions.

CULTURAL VALUES OF SCIENCE

Science not only has its extensive practical values which have been described in the previous paragraphs, but it also has its vital cultural values. At the present time a person who is not educated in the sciences cannot be considered cultured.

Persons such as Edison, Marconi, and Pasteur are greater contributors to society and the world than such men as Shakespeare. More human betterment, alleviation of burdens, and modern improvements have been effected through the labors of these men than of scores of men in the past. A cultured person should understand the past, the present, and the future. It is inconceivable how a person can understand his environment without knowledge of the scientific foundation upon which the environment is built.

THE DISCIPLINARY VALUES OF SCIENCE

The disciplinary values of science which are derived from the study of any subject are the values and trainings which may be transferred to other fields of endeavor. Science can claim to have great values that are transferable into the regular walks of life.

Scientific Method. The first of these trainings which we consider to be transferable is the scientific method by which we mean a distinct and tried method of attacking problems. In brief, it consists of: (1) making an accurate survey of the problem; (2) setting up the method of attacking the problem; (3) collecting data

regarding the problem; and (4) drawing conclusions from the data which have been collected.

The scientific method has expanded into almost every area of human activity. It has been largely responsible for the progress achieved in the fields mentioned under practical values, such as the fields of medicine, industry, business, psychology, and education. It has been made the standard mode of application to all the social and physical problems which are encountered by thinking people.

SCIENTIFIC ATTITUDES. The scientific attitude is the second value derived from the study of science which we consider to be transferable. The attitudes which we call scientific are numerous and are rather difficult to segregate. There have been many scholarly attempts to obtain a clearer understanding of the scientific attitudes. These studies have enlisted the resources of hundreds of science teachers, psychologists, and experts in science teaching to formulate definitions, construct devices for measuring, and devise means of validating the claims of the scientific attitudes. The most comprehensive study, which had for its purpose the determination of the characteristics and elements of the scientific attitudes, was conducted by Francis D. Curtis.[1] Several books dealing with the philosophy of scientific thought were analyzed, from which an outline form of the elements of scientific attitudes was secured. This outline was submitted to 50 high school and 50 college and university teachers of science for evaluation and additions. Fifty-eight replies were received, and a final revised outline was prepared, as follows:

I. Conviction of universal basic cause and effect relations rendering untenable
   1. Superstitious beliefs in general, as "signs" of "good or bad luck," and charms;
   2. "Unexplainable mysteries;"
   3. "Beats all" attitude, commonly revealed by
      a. Too ready credulity.
      b. Tendency to magnify the importance of coincidence.

[1] Curtis, F. D.: "Contrib. to Education, No. 163," Teachers College, Columbia University, 1924, pp. 41-49. Also in "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 267.

II. Sensitive curiosity concerning reasons for happenings, coupled with ideals
   1. Of careful and accurate observation, or of equally careful and accurate use of pertinent data previously collected by others;
   2. Of patient collecting of data;
   3. Of persistence in search for adequate explanation.

III. Habit of delayed response, holding views tentatively for suitable reflection varying with the matter in hand,
   1. To permit adequate consideration of possible options;
   2. To permit a conscious plan of attack, clearly looking forward to a prediction of the probable outcome or solution.

IV. Habit of weighing evidence with respect to its
   1. Pertinence;
   2. Soundness;
   3. Adequacy.

V. Respect for another's point of view, an open-mindedness, and willingness to be convinced by evidence.

Many attempts have been made to isolate and measure the scientific attitudes but with varying success. It is the writer's belief that the time is not far distant when such attitudes can be measured accurately and when this is achieved it will be possible to determine the extent to which science can contribute to the development of the scientific attitude.

Measurement of the Scientific Attitudes. Three studies in this field published during the last 10 years may be briefly summarized.

A. G. Hoff[2] constructed a test for, and attempted to measure the degree of, the scientific attitude achieved by high school seniors according to their major study. The purpose was to determine if those who had studied science as a major subject would score higher on the scientific attitude test than those who had pursued a major study in other areas.

Two hundred items, each designed to reveal one of the five major points in the outline of scientific attitudes, were constructed by the investigator. These were submitted to three experts and 12 additional persons who were either active in education, or served as science teachers and professors of education and psychology, for evaluation of their adequacy for measuring scientific attitudes. The judges were requested to check the correct response to the items. The items were further validated by means of trial per-

[2] Hoff, A. G.: A test for scientific attitude, *School Science and Math.*, *36*:763, 1936.

formances by a group of 65 high school pupils and 55 graduate students. Situations which secured an adequate distribution of responses and were rated average or better by the judges were retained as items in the test, 150 surviving the validating criteria.

Four responses were employed: "true," "false," "insufficient data," and "do not know." Typical items were as follows:

T–F–ID–DK–1. Miss A, a nationally known opera star, decided to discontinue her career after a few years of successful work. It probably is true, as her sister said, that her decision to settle down to a quiet life was due to a mysterious power guiding her destiny.

T–F–ID–DK–2. Mr. A changed oil in his car. After driving his car thirty miles, a bearing in his motor was burned out. Mr. A can collect damages from the company for the cost of repairs.

T–F–ID–DK–3. Mary had a pain in her right side. The physician diagnosed the trouble and performed the necessary operation. Mabel has developed a pain in her right side. She should have an operation performed similar to Mary's.

T–F–ID–DK–4. Mr. A drives an expensive automobile; therefore, he is wealthy.

T–F–ID–DK–5. The president of the United States should not serve more than two terms only because it has been customary not to do so.

The test was administered to five groups of high school seniors in four high schools making a total number of 337 subjects. Performance on the Test for Scientific Attitude was correlated with performance on the Stanford Scientific Aptitude Test, prepared by D. L. Zyve,[3] the American Council Psychological Examination,[4] Iowa Silent Reading Tests for grades 7–12,[5] and high school grades. There was lack of significant correlation with all of the above criteria,[6] indicating that the test measured something different from scientific aptitude, intelligence, or information, and that the scores were unaffected by speed and comprehension in reading. The number of cases was too few to justify the drawing of definite conclusions as to which subject fields developed the greatest amount of scientific attitude in high school pupils. The

[3] Stanford University Press, Stanford University, Palo Alto, 1929.
[4] American Council on Education, Washington, D. C., 1929.
[5] Bur. Educational Research and Service, Univ. Iowa, Iowa City, 1927.
[6] Correlations ranged from .02 to .47.

data tended to show that pupils who had studied languages achieved higher scores on the Test for Scientific Attitude than other groups.

Ira C. Davis[7] devised a test of 66 items which had for its purpose to test for the "possession of the concept of cause and effect relationship and of the ability to distinguish between fact and theory" in high school pupils and teachers in Wisconsin, thereby determining whether they possessed these characteristics of the scientific attitude. The tentative conclusions were that "high school pupils in Wisconsin are not superstitious"; both teachers and pupils fail to distinguish between fact and theory; "pupils seem to have a fairly clear concept of the cause and effect relationship, but they do not seem to be able to recognize the adequacy of a supposed cause to produce the given result"; "many teachers tend to propagandize their material when there is no specific evidence for the statements they make, and teachers do not consciously attempt to develop the characteristics of a scientific attitude. If pupils have acquired these characteristics, it has come about by some process of thinking or experiences outside of the science classroom."

The tests constructed and evaluated by Victor H. Noll[8] contained items providing opportunities for exercise in the following "habits of thinking": (1) accuracy, (2) intellectual honesty, (3) openmindedness, (4) suspended judgment, (5) looking for cause and effect relationships, and (6) criticalness, including self-criticism. The test of 112 items was administered to a group of pupils ranging from grade eight through 12. Two results are pertinent here. One is that a correlation of .30 was found with intelligence; the other shows that the scores on the scientific attitude test tend to increase with increased age and increase in grade level.

Investigations in Scientific Thinking. There have been a few studies on scientific thinking, superstitions, and unfounded beliefs which it may be significant to review.

7 *Science Education, 19*: 117–122, 1935; abstr. in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 269.

8 *J. Abnormal and Social Psych., 30*: 145–154, 1935; also in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 273.

Elliot R. Downing[9] attempted to find out whether pupils acquire skill in scientific thinking as a by-product of the study of science. A test in scientific thinking was administered to approximately 2,500 pupils from grades eight to 12, inclusive.

Upon analysis of the data, a few of the results and conclusions are as follows: (1) A fairly uniform gradual increase in the percentage of correct responses was found from grade to grade. (2) In paired and unpaired groups, it was found that pupils who had not studied science secured higher average scores on the test of scientific thinking. Nine out of 15 cases of paired juniors had higher scores than those who had had two years of science, and a comparison of average scores of seniors showed an advantage (51.6 to 50.5) in favor of those who had had no science studies. The large unpaired groups of juniors and seniors who had not studied science achieved average scores which were .4 and 8.9 per cent greater, respectively, than those of corresponding groups of juniors and seniors who had had science studies for from two to four years. (3) No evidence was found that high school pupils acquire skill in scientific thinking as a by-product of the study of scientific subjects as they are taught at present. (4) General intelligence as expressed by the I.Q. is something quite different from the ability to think scientifically.

Caldwell and Lundeen[10] carried out a study to determine the extent to which junior high school, senior high school, and college students were influenced by certain types of unfounded beliefs, and attempted to determine whether desired attitudes may be achieved by specific instruction. The number of subjects employed ran into the thousands and included secondary school pupils and college students in both rural and urban areas widely distributed geographically in the Middle West and eastern regions of the coun-

[9] *Science Education, 17*: 87–97, 1933; *20*: 121–128, 1936; abstr. in Curtis, "Third Digest of Investigations in the Teaching of Science in the Elementary Schools," Philadelphia, The Blakiston Company, 1939, p. 277.

[10] Unit One: "Do You Believe It?" New York, Doubleday & Company, Inc., 1934. Unit Two: *J. Educ. Research, 22*: 257–273, 1930; *Science Education, 15*: 246–266, 1931. Unit Three: "An Experimental Study of Superstitions and Other Unfounded Beliefs," New York, Teachers College, Columbia University, 1932. Unit Four: *School Science and Math., 33*: 349–413, 1933. Abstr. in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 280.

try. Specially adapted tests were constructed for the junior and senior high school groups and numbered up to 200 items for the senior high school and college groups.

Some of the more outstanding results were as follows: (1) For the junior high school pupils, all items of unfounded beliefs were agreed with by at least some of the pupils; many by at least 50 per cent; a larger proportion of pupils in the midwestern than in the eastern groups and more girls than boys harbored beliefs that were unfounded. (2) With high school seniors, it was found that belief in signs and superstitions prevailed in spite of education, but that education and experience tended to reduce such credulity because fewer older persons and college students believe unfounded ideas. Weather proverbs and misconceptions about natural phenomena, astrology, and phrenology have greater influence than signs of luck, witchcraft, spirits, and misconceptions about health; more girls than boys, women than men, and rural than urban persons are influenced to a greater degree by unfounded beliefs; and college students have heard more of them, but are influenced to a lesser degree than high school seniors. (3) Specific instruction was found to be effective in eliminating unfounded beliefs; belief among young people in unfounded ideas is mainly due to lack of information; subjects gained more with reference to unfounded beliefs than in factual material—32.9 per cent and 23.1 per cent respectively.

Thirty of the most prevalent and influential unfounded beliefs, as indicated by the responses of 200 high school seniors, are listed as follows:

Frost is frozen dew.

Snow is frozen rain.

If animals acquire an unusually heavy coat of fur, that fact foretells a severe winter.

Winters now are less severe than they were thirty or forty years ago.

You can make an accurate estimate of an individual's intelligence by looking in his face.

When squirrels gather an unusual supply of nuts, that fact indicates a severe winter.

When rheumatic people complain of more than ordinary pain in the joints, there will soon be rain.

A man's character may be judged by the features of his face.

If you stare at a person's back, you can make him turn around.

A circle around the moon is a sure sign of rain.

Long slender hands indicate an artistic nature.

Children who are especially intelligent are likely to be weak and retarded physically.

In the days of old, human life was much longer than it is today.

A person who does not look you in the eye is likely to be dishonest.

Any physical or mental disease can be produced by thinking too much about it.

Misfortunes never come singly.

A high forehead indicates superior intelligence.

A square jaw is a sign of strong will power.

During long periods of drought, individuals or groups of individuals by their prayers can cause it to rain.

Brains and beauty rarely go together.

If March comes in like a lamb, it goes out like a lion.

Fat people are always good natured.

Dew falls from the sky.

Some snakes charm birds and other animals, even human beings.

The general form and condition of the hand, the shape and markings on the fingers indicate fitness for social, intellectual, or practical work.

Red hair is a sign that the possessor has a violent temper.

Brunettes are more trustworthy than are blondes.

A snake's tail will not die until sun-down.

If you find a four-leafed clover it will bring you good luck.

If the ground-hog sees his shadow on ground-hog day (February 2), there will be six weeks of bad weather.

Sources of superstitious beliefs were studied by Maller and Lundeen.[11] A questionnaire containing 50 items was constructed by the investigators and was filled out by 113 boys and girls of junior high school age and 66 boys of senior high school age. The subjects were asked to indicate whether they believed the items to be "true," "false," or "uncertain as to its truth or falsity"; and whether the agencies, namely, the home, school, church, friends, books, newspapers, or observation had represented the idea as true or false. An analysis of the data showed that (1) the average pupil believed in 30 per cent of the items and disbelieved in 55 per cent and was uncertain in 15 per cent; (2) younger pupils and girls believed in a greater number of the items than older pupils and

[11] *J. Educ. Research, 26*: 321–343, 1933; abstr. in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1938, p. 294.

boys; (3) friends ranked first and the home second as a source of fostering superstitions; while educational sources (church, school, newspapers, and books) and observation contributed the least to belief in superstitions; (4) the order of influence in correcting superstitions was observation, education, home, and friends, and the corrective influences were greater for boys than girls and for older than younger pupils; (5) pupils preferring as reading matter books on science and invention were less superstitious than those preferring books of fiction, adventure, and mystery, and (6) the same source may be fostering superstition in some individuals and correcting superstitions in others.

A study of health misconceptions of seventh, tenth, and twelfth grade pupils was made by E. Benton Salt[12] by means of a preliminary test composed of 300 true-false items secured from five sources of popular misconceptions regarding health. The test was administered to a representative group of 635 pupils in the grades mentioned. After validation procedures, 118 false and 32 true items were used as the final test which covered the areas of mental health, oral hygiene, food and nutrition, physical activity, organic function and disturbance, contagions and infections, preventive measures, safety and first aid, advertised products, and miscellaneous health misconceptions. Responses to the test were secured from 3,221 pupils in the seventh, tenth, and twelfth grades in 26 schools for white pupils, and from 592 pupils of these same grades in six schools for negroes. Socioeconomic status and health information were correlated with the health information test.

The findings were quite similar to those found in the studies on superstitions previously described. Unfounded beliefs with regard to health are prevalent among the grade levels studied; misconceptions decreased as the grade level increased; girls subscribed to a greater number than boys in all grades; and negro children in all grades studied possessed misconceptions to a greater degree than white children. Wrong ideas relative to physical activity and advertised products ranked, respectively, first and second;

[12] Unpublished dissertation for the degree of doctor of education, New York University, 1936; abstr. in Curtis, ''Third Digest of Investigations in the Teaching of Science,'' Philadelphia, The Blakiston Company, 1939, p. 298.

and contagions and infections and mental health ranked last in prevalence of misconceptions. The relationship between factual health knowledge and misconceptions, and socioeconomic status and health misconceptions, was found to be negligible.

The relationship between natural science beliefs and attitudes and social and intellectual factors was studied by J. W. Wrightstone.[13] A test was constructed containing 28 items on true generalizations and 52 on false generalizations or superstitions, and 10 items on scientific thinking. The results of the test were correlated with intelligence as measured by the Otis Self-Administering Test, and socioeconomic status. It was found that (1) there was a very low positive correlation between verbal intelligence and natural science beliefs; (2) that natural science knowledge influences the capacity to distinguish between proved generalizations and unfounded beliefs in natural science; (3) that there is a negligible correlation between socioeconomic status and natural science beliefs of high school pupils; and (4) that girls showed significantly less discriminating power regarding science beliefs than boys.

Conclusions Regarding Scientific Attitudes and Scientific Thinking. Development of the scientific attitudes in secondary school pupils should be considered by educators and science teachers as an important outcome resulting from the study of the sciences. As scientific attitude appears to be a characteristic which is different from general intelligence, and since it is a desirable attribute for an individual to possess to an appreciable degree, it merits rating as a major objective in science teaching.

Any evidence that those pupils who have studied science in the secondary school do not possess the scientific attitudes to a greater degree than those who have not received this training may be due to inefficient teaching. Such an apparent deficiency may also be a result of inadequate understanding and application of the scientific information learned and is an indictment against the present science program in both the elementary and the secondary school.

Dogmatic and superstitious beliefs should be singled out and

[13] *Science Education, 17*: 10–12, 1934; abstr. in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 302.

corrected in terms of the scientific knowledge available to these pupils. As the learning activities in the secondary school sciences progress the correction of these erroneous beliefs should be made in the units and problems where the true facts can be most effectively presented. For instance, the truths about health can replace false notions regarding health during a study unit on the human body; weather superstitions may be eradicated during a study unit on weather; beliefs regarding the origin, change and destruction of the earth may be replaced by more accurate scientific conceptions during a unit on the earth; and the like.

The scientific attitudes, scientific method, and scientific thinking can be further developed in the specialized science courses in the secondary school. Since about 80 per cent of our youth end their formal schooling at the end of the twelfth grade it is paramount that secondary school science make as great a contribution as possible in the area of scientific thinking. Such a contribution should materially elevate the level of thinking in our democratic society and materially strengthen it.

STUDY QUESTIONS

1. What evidence is there that science is the byword today?
2. What are the contributions of science to business? To medicine? To astronomy? To meteorology?
3. What are the cultural values of science? The disciplinary values?
4. What are the main aspects of the scientific attitude?
5. What is the status of the measurement of scientific attitudes?
6. What is the relationship between the scientific attitude and scientific method?
7. How does the study of science modify the scientific thinking of persons?
8. How may unfounded beliefs be corrected in the minds of the secondary school pupils?
9. What are some of the unfounded beliefs that seem to persist even after education or the study of science?
10. How do boys and girls compare as to the prevalence of unfounded beliefs?

ADDITIONAL PROBLEMS AND PROJECTS

1. Report to the class on one or more of the studies on scientific thinking and health misconceptions.
2. Prepare a test on scientific attitude or on unfounded beliefs and administer this test to a group of secondary school pupils.
3. Write a comprehensive paper on the educational values of science.

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3

The Science Teacher's Social and Professional Responsibility

SOCIAL RESPONSIBILITY

Responsibility to the Community. The science teacher has two major social responsibilities, the first being to the community and the second to the school. The first is a matter of adjustment to the community. When the science teacher goes into the community to help in the educational, moral, and social growth of the children of the city, village, or county, it is paramount that he be one of them. While to some extent practicing the old maxim, "While in Rome, do as the Romans do," the teacher should attempt to maintain a standard of living and a level of moral and social conduct that will serve as a good example for the community. In other words, a teacher should not come into a community as an infallible, domineering "tin god," but to be a friend, a helper, and a leader of the community. This can be done by maintaining the proper relationship with the parents and the children of the community. One need not be aloof, cold, and unfriendly to achieve respect. More respect is achieved by the exhibition of sympathy, understanding, and insight into the social and economic problems. The attitude should be one of friendliness, not familiarity.

A second responsibility which the science teacher has to the community is that he should provide a certain amount of leadership in civic, religious, and other community affairs, especially affairs having to do with education and recreation. While it is not mandatory that the teacher take the responsibility of being a Sunday school teacher; if he feels that this work is vital and important and he enjoys participating in it, he is apt to be valuable as such to the community. The writer's opinion is that it is better to refuse to participate in religious activities and efforts which are contrary to his interests and conscience rather than to feel coerced

into such work and then not render the service properly. If such responsibility is accepted, the teacher should carry out his work in a complete and responsible way and should not be negligent or undependable in the execution of his responsibilities. It is just as important to be prompt to teach a Sunday school class as to be on hand to teach a class on a regular school day because the administrators and supervisors of such a program are expecting and depending upon the reliability of their assistants.

Responsibility to Fellow Teachers. It is the duty of every teacher to coöperate with his fellow teachers and administration. It is said that cöoperation means to ''so conduct oneself that other people may compatibly work with one.'' In modern society the days of rugged individualism are past; we must coöperate with our fellow men in every activity in which we engage, whether it be for leisure pastime or for maintaining our livelihood.

Responsibility to the School Board. The responsibility of a science teacher to the school board, to whom the first allegiance belongs, is of course the greater responsibility. The teacher should put his best efforts into the job for which he is hired. Vital energies and time should not be dissipated in other activities, whether they be worth-while and productive or destructive activities. It is often true that many teachers who have had the misfortune (if it could be called such) to be placed in rather undesirable communities, especially during their first years of teaching, become lonesome and homesick. They leave the community during each week end, therefore, and expend energies on activities which are not worth-while, or place too much strain on their constitutions in traveling home and returning. As a result, they are inefficient during the first few days of the week, or even enervate themselves to the extent that illness ensues as a result. This, of course, is not fair to the employer or the community. Often, when illness results from unwise activities or overindulgence in them, the teacher expects the school board to pay his salary while he is recuperating though this illness is not a result of any misdemeanor on the part of the board. Again, it is unfair to the employer or the community when teachers dissipate their energies on other remunerative activities, such as refereeing athletic events in communities so far distant that proper rest to prepare for the next

day's work is impossible, and when persons are expending their vital energies on private interests rather than on the position which maintains their livelihood. The school board has the right to expect value received for what the teachers are being paid.

Responsibility to the Administration. It is likewise paramount that the teacher coöperate with the administration which directs and guides the policy of the school. This does not mean that the teacher should not have personal views on matters of school administration and teaching. He has a right to express these views and should do so freely to his superiors and should feel free to provide and give arguments to support his point of view. This discussion should be conducted with a respectful and friendly—not a belligerent—attitude. The fact must be remembered that the principal or the superintendent has been hired to direct and supervise the education of the children of that area, and that his decisions and wishes should be final after all arguments and views have been presented. If the teacher is not convinced that his superior is correct, he should acquiesce nevertheless and should accept the decisions of this final authority in a coöperative manner and without reserve. If the difference in opinions between superior and teacher are of such a degree as to render the latter seriously unhappy, it might be wiser for the teacher to seek an environment and conditions under which happiness might be achieved. Underhanded unjust criticism is not ethical and should be avoided. It is better to strike forward and express dissatisfactions and discontent directly to the administrator rather than to resort to "backbiting."

Responsibility to the School. A third important responsibility with relation to the school which a teacher should accept is the care of equipment. There is no department in any educational institution or system which has a larger amount of valuable materials and equipment under its care than has the science department. Care should be exercised to the fullest extent of the teacher's capacity. It should be treated as though it were his own. It must be remembered that the taxpayers of a community have paid their hard-earned dollars for this equipment. Many pieces of apparatus in physics cost from $25 to $50 and more. A limited list of supplies and equipment needed in a general science room at the present time requires the expenditure of approximately $300 to $400.

Equipment for an adequate physics room will cost as much as $1,000. Likewise, supplies and equipment for a chemistry department are valued at hundreds of dollars. Care should be taken that this equipment is neither stolen nor destroyed. All valuable pieces should be kept under lock and key and should not be available for use to the general pupil group without the consent of the instructor. Supplies should be used conservatively, and pupils should be constantly reminded to follow this rule. Unless this is done, large amounts of supplies and chemicals will be wasted by being thrown into the wastebasket or washed down the drain.

Adequate care of the classroom is the responsibility of the science teacher and a well-cared-for classroom is readily observed by the principal, superintendent, and members of the board of education. The shades should be properly handled—not handled carelessly—because these things have a high value in terms of comfort (of the children) and money. The writer has frequently observed that windows have been opened, especially in the spring and fall, and the shades pulled down so that they dangle and are whipped by the currents of air, causing them to become folded and worn. There is no need for shades to be pulled below the level of the window.

The desks should be kept in good condition. Constant vigil should be employed over the destructive impulses of pupils toward the furniture in the room. Writing or drawing on desks should be strongly discouraged. It is wise to ask pupils, who are given to scratching and scribbling during discussions, to keep a piece of paper before them on which to make marks and draw figures. This will save the varnish on the tables and desks. As soon as the marks break through the varnish of the desks, the surface must be scraped to remove them, while pencil marks can be removed by a moist cloth. The best way to prevent marking and cutting of desks is to keep it from beginning, for a mark, figure, or a cut in the desk is of suggestive power and may cause pupils to continue the mutilation.

Thumbtacks should be placed only on bulletin boards. Pupils as well as teachers would consider criminally negligent anyone who placed thumbtacks in the piano or dining-room furniture at home. The woodwork and furniture in the school building is just

as important and is probably expected to last longer than that in the home. On the average, a school building is intended to be fit for use for from 50 to 75 years. It can readily be observed, then, that indiscriminate destruction of these features of a room or building will seriously impair the length of life of at least these parts of a building. In one large city school system, the misdemeanor on the part of the teacher of pushing a thumbtack into the baseboard, door panel, or window sill is practically cause for dismissal.

There are many other features concerning the care of a room which have to do primarily with "housekeeping." Care should be taken to see that the teacher's desk is in fairly good order at all times, especially after school, so that the janitor has an opportunity to clean and dust it properly. Blackboards should be erased if material on them is not designed to be saved for any future date. Attention should be given the matter of waste paper left by pupils in the desks, on the top of the desks, or on the floor. Training pupils to be responsible for the tidiness of the room can contribute to improvement in pupil character.

Textbooks and Study Courses. Selection of textbooks is a responsibility of the science teacher. The science teacher is considered to be a person specially trained in this field and for this reason should be of positive assistance to the principal or superintendent regarding the type of texts or instructional materials which are to be used in the science field. Hence the science teacher should be qualified to render, and be willing to contribute, this service. It is not always possible or advisable that the teacher should have the right to order or select the textbooks, but he should have the authority to recommend, leaving the final decision to the superior officer with whom this responsibility undoubtedly should lie. The construction of courses of study is a responsibility that the science teacher should accept. The need for this type of service is becoming less necessary and desirable as the commercially prepared instructional materials are improved. It is the writer's opinion that the average teacher, including the science teacher, can do more efficient teaching if well-prepared commercial materials are used instead of teacher-prepared materials. Teacher-prepared materials are generally much inferior because most average teachers are not

trained nor have they adequate time to do the job of preparing study outlines and units. Some school systems, however, still believe that teachers should do this work and the science teacher should therefore be prepared to do so.

Extracurricular Activities. Every teacher, including the science teacher, should expect to care for at least one or two extracurricular activities, possibly one major activity and one minor activity. These responsibilities should be accepted and executed to the best of one's ability. If an extracurricular activity is assigned which a teacher feels unqualified to perform, it may be wise to speak to the superior officer regarding this, rather than to attempt the task with insufficient preparation and lack of enthusiasm and interest. Often, corrections can be made for the betterment of all. If the teacher believes that the activity is too heavy or that the load is too great, it is likewise a wiser policy to make this known to the superior officer so that adjustments may be made instead of doing a half-job, as often happens.

PROFESSIONAL RESPONSIBILITY

Grading of Pupils. The grading and rating of pupils is probably the most important responsibility of the teacher. It is his responsibility to find out everything possible about each and every pupil under his care so that each child may be served to the best advantage. Many in education hold that the teacher should receive a child into his class knowing nothing about that child because, it is claimed, previous information regarding a child will cause a teacher to be prejudiced or to harbor unfair preconceived notions regarding the child which will militate against proper and fair treatment of the pupil. This philosophy, however, is fallacious because it takes weeks and months and sometimes years to become acquainted with a child, and under such conditions most of our children would never be known by the teachers. Whenever a physician wants to make an accurate diagnosis of a patient, he always secures all the information possible regarding that patient. Records are kept in all up-to-date clinics and maintained cumulatively, to be referred to so that better ministration to the patient's health can be achieved. A wise doctor never sees a patient until his cumu-

lative record is carefully studied, after which the patient is asked to enter the consultation or examining room.

The same problem presents itself in the handling of a child by a teacher because the teacher is the child's mental and emotional doctor. If the teacher knows the home, economic, and health conditions of a child, he is better able to judge whether or not a child is accomplishing all of which he is capable. If home conditions are unhappy, the child is bound to be emotionally disturbed, causing in him a nervous and irritable condition at school; also, it may cause a lack of concentration and attention, and reduce the ability to pursue tasks continuously.

Critical physical impairments may seriously handicap the progress of a child. Among such handicaps are defects of hearing and sight and possibly defects in motor ability. The teacher should be aware of each instance of such defects so that proper adjustments can be made. The writer has seen many children doomed to failure because their personalities have been destroyed primarily as a result of having been under teachers who were unaware of the presence of these handicaps.

The teacher should be a guardian of the pupils' health and to this end should be familiar with the health record and the current health status of the pupils. The child's mental and physical health should be guarded by careful attention to the light, heat, and emotional conditions in the schoolroom. The conscientious and emotionally sensitive child should be protected as far as possible from severe disciplinary techniques which are occasionally necessary. Such cases should be handled outside the classroom and not in the presence of the rest of the class. Pupils have a right to be working in a happy wholesome environment free from fear and emotional upset.

After absence due to illness great care should be exercised in requiring an undue amount of make-up work. It must be remembered that the child will tax his energy to the maximum in keeping up with the regular classwork without making up tasks which were missed while absent. It may be a far wiser policy to forget entirely about the work missed even in more solid subjects such as mathematics, chemistry, and physics. Some teachers claim to build character in these unreasonable requirements, but they forget that

health is the first thing to be considered. The loss of a few weeks of subject matter will never matter much in the child's life. Lowering of resistance or maintenance of a low state of energy may be very harmful to the present and ultimate health status of the pupil.

The source for securing information regarding the individual pupil is, of course, the cumulative record. Each record should be available to every teacher and should be used continually so that the teacher may know the child's probable mental ability, physical and economic status, and conditions in the home.

The information regarding the past and out-of-school environment of the child is, of course, an insufficient base for grading. Primarily, the grades should be based upon a child's classroom work but from the preceding discussion it is clear that these other sources of information should be employed to assure a more just rating. In order to make out grades based upon the classroom work of the child it is evident that enough data on the classroom work should be secured. It is not adequate to use the scores on a single quarter examination, or even two examinations in the quarter. It is necessary that the daily classwork be evaluated and recordings made in some form of permanent record.

It is more difficult to secure an adequate sampling in some subjects than in others. Generally, at least two or three such samples of the child's work should be recorded in the permanent record accompanied or supplemented by the scores of a reliable unit examination. This should make up a satisfactory basis for the grading of children. It is also necessary to record observational impressions of the child which can be secured during directed study periods, in the laboratories and through other opportunities of observing the child at work.

It is a duty of the teacher to maintain constant vigilance over the child to see that every opportunity is provided for its maximum growth. The author believes that failures are of rare practical value, and they may be and are vicious and destructive in the disintegration of personalities. Also, many teachers fail to take cognizance of the destructive effects which failures have upon the child's emotional, social, and physiological make-up. A high number of failures does not necessarily mean that the teacher has maintained high standards. In more cases than not it indicates that the teacher

has done a poor job of teaching. There is much truth in the maxim that "It is more difficult to pass a child than to fail a child." To see that a child passes in his subject requires alertness and stimulating classroom work, sympathetic interest, and love for the children and the job of teaching. Studies show that pupils who repeat subjects very rarely do any better. On the contrary, in many cases they do more poorly than during the first attempt at the subject.

It is a further responsibility of the teacher to motivate the pupils to do work of adequate amount and quality to equal the minimum standards. If this is done, the threats of failure are not necessary. It has been the author's experience that such a failure has no significant effect upon the pupil's performance. Children of the elementary and secondary school level are too young to understand the results or the consequences of retardation due to failure. A much stronger force is their interest in the task at hand. The teacher can motivate pupils by making their work such that they will succeed continually. This may be done by making the beginning tasks commensurate with the pupil's ability, and gradually increasing the difficulty as the child becomes more proficient. In this manner, greater achievement both in quantity and in quality can be secured than by continual threats of failure and by reprimanding the child with tasks not arranged in the graduative manner.

The teacher must, of course, be kind, understanding, and sympathetic at all times. He should use every opportunity to compliment the child when success is achieved, thus providing the driving force of enthusiasm and the feeling of success to carry on to higher levels of achievement. The teacher must have a broad background of information in the field of the subject matter, in the psychology of learning, and in the subject of mental hygiene which deals with the emotional development of children. Further, the teacher must be enthusiastic, robust, and healthy, with the proper attitude toward children and society, in order that the children may become aware of this rosy atmosphere which inevitably is attached to such a personality. If all these factors are integrated properly by the good judgment of the teacher, the pupils will automatically be motivated to work to their capacity. The attitude of throwing out the subject matter and expecting the pupils to "take it or leave it"

is a thing of the past. Teachers today are expected to teach and not just dole out information.

KEEPING PROFESSIONALLY UP-TO-DATE. The last but not the least responsibility of the teacher is to keep up-to-date. During the last 25 or 30 years the job of teaching has been changing rapidly from a vocation to a profession. The acceptance and use of the scientific method has made it possible to secure information of both technical and practical material which has been the foundation of all the progress in the profession of teaching. Advancement in the field of scientific methods of teaching has been as great as in other fields of endeavor such as medicine, transportation, and communication. Change is constantly taking place, not only in the subject matter which is taught but in the fields related to the teaching of the subject matter, such as general psychology, educational psychology, curriculum construction, school administration, and personnel administration. The education and training of a teacher does not stop with the college degree, as this is only the beginning. This training embodies the laying of a foundation for greater service to society, and the real contribution and growth in the field of teaching naturally continues after these basic trainings have been given. Many of the principles set up in the psychology of education, emotional development, and techniques of measurement cannot really be understood until the teacher has had several years of experience in the field. Therefore, it is evident that the real functional preparation for teaching is done by means of what many call in-service training.

After receiving the bachelor's degree, a teacher who plans to remain in the profession as a life work should plan to attain the master's degree in not less than five years; and after that, in order to keep up with progress in his field to a minimum extent, should attend at least six weeks of summer sessions during every third summer. In addition to this attendance at summer sessions, much reading of current professional magazines and periodicals in both the subject matter field and professional field is necessary to keep abreast with advances in these areas. Further, the teacher should plan to attend at least one or two professional meetings or conventions during the year, and support financially by membership from one to five professional organizations.

STUDY QUESTIONS

1. To what extent should the teacher adjust to the community in which he is employed?
2. What are the responsibilities of the teacher to the community?
3. What are the responsibilities of the teacher to the school and the board of education?
4. Give the responsibilities of the teacher with relation to the care of equipment and the classroom.
5. Why is it a serious misdemeanor for a teacher to use thumbtacks or drive nails in places other than those provided, such as bulletin boards?
6. Give the responsibilities of the teacher with regard to extracurricular activities.
7. Discuss the work of the teacher in the selection of textbooks and curriculum instruction.
8. Why should a teacher accept the responsibility of grading pupils as a serious problem?
9. What are the arguments favoring a 100 per cent promotion policy in a secondary school?
10. Does a large number of failures necessarily mean high standards on the part of the teacher? Why?
11. Name some principles which a teacher should follow in the preparation of the pupils' marks.
12. Name some things a teacher may do to help a pupil work to his capacity.
13. How may a teacher keep professionally up-to-date?

ADDITIONAL PROBLEMS AND PROJECTS

1. Write a paper on "The Responsibilities of the Science Teacher."
2. Prepare a discussion on the advantages and disadvantages of the 100 per cent promotion plan for secondary schools.
3. Prepare a discussion on the thesis, "It is Easier to Fail a Child Than to Pass Him."

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UNIT TWO

The Content of Science in the Secondary School

As scientific knowledge has grown to such large proportions in a relatively short time, it is mandatory that those portions which prove to be most functional in daily living be selected for learning experiences in the secondary school. In order to effect a proper selection of scientific facts and understandings that will promote optimum growth in preparation for child and adult life, it is necessary to correlate the aims in science education with the aims in general education. The Seven Cardinal Principles and aims based upon the needs of modern youth in personal living, and social and economic relationships may serve as guides. General and specific objectives which are of less comprehensive nature and which minister to the broad aims of science education, may be chosen and serve as a more specific guide in choosing appropriate learning experiences.

The science curriculum is determined on the basis of the accepted objectives. Learning experiences which will achieve the objectives must be carefully selected. Criteria of selection are formulated with the aid of studies in various areas such as pupil and adult needs and interests, surveys of present practices, and analyses of current literature. These criteria of selection may be supplemented by expert opinion and the best thought in educational philosophy and psychology.

The textbook is an important form in which to prepare accepted instructional materials. Such a compact preparation which is based upon the latest information in the area of science teaching, and usually integrates the best efforts of educational psychology, philosophy, and practical teaching experience, serves as an excellent basis for an efficient curriculum. Criteria helpful in the selecting of textbooks, suggested curricula for the junior and senior high school, and evaluation of these curricula are presented in this unit.

4

The Aims and Objectives of Science Teaching

PHILOSOPHY OF SCIENCE TEACHING

A philosophy of science teaching is made up of the aims and objectives of teaching in general and of science teaching in particular. In order for a teacher to have an adequate and intelligent foundation for efficient administration of a class, a thorough background in educational philosophy is necessary. Such a foundation enables a teacher to exercise wise judgment in all activities which take place in the classroom. This can be called a "long view" which enables a teacher to see and keep in mind the aims which are attempted to be reached by means of the activity in operation at any particular time. It can be compared to the ideals which we strive for continually and never reach. It is like the little girl who chases the rainbow or the young boy who hooks his wagon to the star, but it still serves as a guiding light to carry the individual along life's highway so that energy will be conserved and faltering will be of less frequent occurrence.

CARDINAL PRINCIPLES

The objectives of science teaching may be classified into categories which are different in scope. First, we may take the general aim of education which is defined in scores of terms, but some of which seem to be functional at present: "Training for Efficient Participation in a Democratic Society," "Training for Citizenship," "Individual Development," "Social Efficiency," or the like. Such aims may be considered as the general aim or aims of education. If this general aim of education is analyzed, the Seven Cardinal Principles which were developed by the Committee on Reorganization of Secondary Education two decades ago seem to serve the purpose even at the present time. These are: Health,

Command of Fundamental Processes, Worthy Home Membership, Vocation, Citizenship, Worthy Use of Leisure, and Ethical Character. Efforts to improve upon these cardinal objectives have not been fruitful up to the present time because these seem to comprise all phases of successful living.

VARIOUS STATEMENTS OF OBJECTIVES

The Progressive Education Association's Committee on the Function of Science in General Education attempted to express the aims of education in a more functional plan. The statements are organized under the major aspects of living, as follows:[1]

I. Meeting the needs of adolescents in the area of personal living.
   - The need for personal health.
   - The need for personal living.
   - The need for a satisfying world picture and a workable philosophy of life.
   - The need for a range of personal interests.
   - The need for esthetic satisfactions.

II. Meeting the needs of adolescents in immediate personal-social relationships.
   - The need for increasingly mature relationships in home and family life.
   - The need for successful and increasingly mature relationships in age mates of both sexes.

III. Meeting the needs of adolescents in social-civic relationships.
   - In the school and community.
   - In the broader community—state and nation.

IV. Meeting the needs of adolescents in economic relationships.
   - The need for emotional assurance of progress toward adult status.
   - The need for guidance in choosing an occupation and for vocational preparation.
   - The need for wise selection and use of goods and services.
   - The need for effective action in solving basic economic problems.

V. Encouraging reflective thinking.

On studying these objectives it is evident that each of the Cardinal Principles is included. Stated in this manner, the aims of education may be more understandable to the average teacher and may be made to function to a greater degree in the daily direction of pupils in the classroom.

[1] Thayer, V. T., *et al.:* "Science in General Education," Part II, New York, D. Appleton-Century Co., 1939.

A second category which we may call general objectives may include educational learning products which are ministered to and achieved to a greater degree than provided for by the aims of the Seven Cardinal Principles previously described. These general objectives may be the attitudes, interests, skills, habits, and understandings which are achieved in participating in the activities provided in our schools. Science ministers to all these objectives. There are two very important objectives which the teaching of science develops: first, a scientific attitude, and second, the scientific method, which were described in Chapter 1.

The attitude of appreciation of the marvels of the universe and nature can be developed only through an understanding of the facts and workings and laws of nature. Among these appreciations are those of the conveniences and products of modern science, such as home appliances, transportation facilities, building, construction of skyscrapers, highways, and railroads, and of the achievements of medicine and engineering. Skills may be taught through the study of science; among these skills and objectives are skill in finger dexterity, skill in the use of the scientific method of solving problems, and skill in creative endeavors.

An analysis of the objectives listed in courses of study in general science by Wilbur Beauchamp[2] holds true for the entire program of science teaching in the secondary school. These objectives are as follows:

A. Knowledge.
  1. To acquire information about science.
  2. To acquire knowledge which will produce a better understanding of our environment.
  3. To acquire the knowledge necessary to correct superstition and erroneous beliefs.
  4. To acquire a scientific vocabulary.
  5. To acquaint the student with the source of scientific knowledge.
  6. To acquire information concerning the lives of the great men of science.
  7. To acquire a body of facts which will enable one to read scientific literature.
  8. To acquire a knowledge of the fundamental principles of the subject.
  9. To acquire a knowledge of the application of principles in industry.

[2] Instruction in science, *Bull. of the U. S. Bur. Education,* No. 17, Monograph No. 22, 1932, United States Department of Interior, Office of Education.

10. To acquire the knowledge necessary for future courses in science or to prepare for college.
11. To acquire knowledge which will function to secure the objective states in the bulletin on Cardinal Principles of Secondary Education.
    a. Health.
    b. Citizenship.
    c. Worthy home membership.
    d. Vocation.
    e. Worthy use of leisure.
    f. Development of ethical character.

B. Exploration (or orientation).
1. To give the pupil a view of the field of science so that he may explore his interests, capacities, and abilities.
    a. As a basis for the election of further courses in science.
    b. As a basis for the selection of a vocation.
    c. To acquire new fields of interest.

C. Abilities.
1. To develop the ability to think scientifically.
    a. To develop reliance on facts.
    b. To develop the power of interpretation.
    c. To develop the power of observation.
    d. To develop the ability to form independent judgments.
    e. To develop the ability to evaluate.
    f. To develop the ability to generalize.
    g. To develop the ability to locate problems.
    h. To develop the ability to plan prior to execution.
    i. To develop the ability to gather data systematically.
    j. To develop the ability to recognize defects and errors in conditions and processes.
2. To develop the ability to use the scientific instruments common in the laboratory.

D. Attitudes.
1. To develop a scientific attitude as shown by ability—
    a. To view facts objectively.
    b. To be free from dogma and superstition.
    c. To hold one's conclusion as tentative and to suspend judgment until facts are secured.
    d. To revise one's opinions if the evidence warrants.
    e. To have a spirit of inquiry.
    f. To be open-minded.
    g. To have a conviction of the universality of the cause and effect of relationship.
2. To develop attitudes of appreciation of—
    a. The contributions of scientific method.

b. The contributions of science to mankind.
c. The great men of science.
d. Expert judgment.
e. Nature.
f. One's responsibility in the world.
g. Natural laws.

E. Ideals and habits.
1. To acquire ideals or habits of accuracy, persistence, honesty, self-control, truth, etc.

F. Interests.
1. To acquire an appetite for investigations in science.
2. To acquire an appetite for scientific reading.
3. To acquire an interest in taking more science.
4. To acquire an interest in nature.
5. To acquire interests in vocational fields.
6. To acquire wholesome interests which may be used to enjoy spare time.

The preceding objectives may be classified as general objectives. These objectives are more narrow in scope than the aims of education which we chose to be the Seven Cardinal Principles. These general objectives cannot be measured as to the degree to which we achieve them in the classroom, but we know that each and every unit in science or in any other subject should minister to them. No one unit will minister to the entire extent to any one of these general objectives, but each unit will achieve some growth in these areas.

Objectives which may be classified as specific objectives are those which can be objectively measured in the classroom. Therefore, these would be the specific learnings and skills and interests which are actually developed through the classroom activities. For example, the specific objectives for a unit in science would be the definite problems which are solved in the unit. The specific objectives for a science subject would be the major unit problems or themes which are studied. For instance, in general science some of the specific objectives would be "to know the use of air to man"; "how a pure water supply is achieved"; "how electricity is of use to man"; and the like.

It is true that an attempt is being made at present to make an objective measurement of attitudes, interests, and skills which have hitherto been unmeasurable, but the achievement at present has not been of great practicality. The day may come when the

degree with which growth in the areas of the general objectives occurs may be measured with considerable accuracy, and when such time comes, these may be classified as specific objectives.

The Committee on Science Teaching of the National Society for the Study of Education formulated a list of specific objectives in science which can be developed at any grade level. The Committee termed these generalizations or principles. The more elementary phases of each generalization may be developed in the lower grades and the more complicated understandings relative to the principles can be taught at the succeeding grade levels continuing through college. A list of these principles is as follows:[3]

1. The sun is the chief source of energy for the earth.
2. Through interdependence of species and the struggle for existence a balance tends to be maintained among the many forms of life.
3. The earth's position in relation to the sun and moon is a determining factor of life on earth.
4. All life comes from life and produces its own kind of living organism.
5. Matter and energy cannot be created or destroyed, but may be changed from one form to another.
6. Species have survived because of adaptations and adjustments which have fitted them to the conditions under which they live.
7. The energy of solar radiation is continually working changes in the surface of the earth.
8. There have been profound changes in the climate, not only of certain regions, but also of the earth as a whole.
9. The evolution of the earth has come as a result of natural forces.
10. Units of time are defined by the earth's movements in relation to the sun.
11. All life has evolved from simple forms.
12. The earth seems very old when its age is measured in the ordinary units of time.
13. Distances in space seem extremely vast when compared with distances on earth.
14. The physical environment has great influence on the structural forms of life and on plant and animal habitats.
15. Man can modify the nature of plant and animal forms through application of his knowledge of the laws of heredity.
16. There is a great variety in the size, structure, and habits of living things.

[3] National Society for the Study of Education: "A Program for Teaching Science," Thirty-first Yearbook, Part I, Bloomington, Ill., Public School Publishing Co., 1932, p. 53.

17. There are processes that go on within an organism that are vital to its continued existence.

18. Chemical and physical changes are manifestations of energy changes.

19. There are fewer than 100 chemical elements.

20. Every substance is one of the following: (a) a chemical element, (b) a chemical compound, (c) a mechanical mixture.

21. Certain material substances and certain physical conditions are limiting factors to life.

22. Light is a limiting factor to life.

23. Sound is caused by waves which are produced by a vibrating body and which can affect the auditory nerves of the ear.

24. Gravitation is the attractive force that influences or governs the movements of astronomical bodies.

25. Machines are devices for accomplishing useful transformations of energy.

26. Any machine, no matter how complicated, may be analyzed into a few simple types.

27. The properties of the different elements depend on the number and arrangement of the electrons and protons contained in their atoms.

28. All matter is probably electrical in structure.

29. The applications of electricity and magnetism in the home and in industry have revolutionized the methods of living of many people.

30. Heredity determines the differences between parents and offspring as well as the resemblances.

31. The kinetic energy of the molecules determines the physical states of matter.

32. The gravitational attraction between the earth and a mass of unconfined gas or liquid causes the pressure of the liquid or gas on the surface of the earth.

33. Liquid or gas pressure is exerted equally in all directions.

34. Chemical changes are accompanied by energy changes.

35. A change in rate or direction of motion of an object requires the application of an external force.

36. Radiant energy travels in straight lines through a uniform medium.

37. Electricity is a form of energy that results from disturbing the position or the regular paths of electrons.

38. In a chemical change a quantitative relationship exists between the amounts of substances reacting and the amounts of the substances that are the products of the reaction.

Many authorities in the teaching of science object to the idea proposed by the Committee. One contention is that it is difficult to organize instructional materials around these principles and still maintain the environmental approach to the study of science. Such generalizations may be more easily taught on the college level. On

the secondary and elementary school levels it is necessary to intersperse these broad ideas into environmental units where they may be stressed. With proper adaptation it is possible and compatible with modern educational psychology to employ the principles as unit themes in providing learning experiences for elementary and secondary pupils.

The Committee also lists principles which can be considered as specific objectives for biology, chemistry, and physics.

Principles in Biology

Generalizations adaptable to special subjects may be further developments of the principles previously listed for science as a whole. This can be expanded to greater advantage in the more specialized areas of biology, chemistry and physics. Further understanding is thus achieved on progressively higher levels as the pupil participates in additional learning experiences.

The following principles in biology are functional in teaching this subject in the senior high school. The major principles can be utilized as the basic unit themes, and the minor generalizations can be effective minor problems contributing to the broader concept of the unit with each generalization developed by means of detailed learning experiences adapted to pupil environment. The learning experiences should consist of experiments, observations, and reading to a sufficient extent to assure adequate understanding of the concept. The principles in biology may be stated as follows:[4]

1. Energy cannot be created or destroyed, but merely transformed from one form to another.
    a. Energy required by the living organism to carry on its activities is generated by the oxidation of its substance, so liberating stored-up chemical energy.
    b. The oxidized substance is replaced by rebuilding it out of the foods taken.
    c. Since living material (protoplasm) is protein in character, containing nitrogen, a certain proportion of protein foods is essential.
    d. Substances used as foods should not contain any deleterious compounds. Stimulants and narcotics cause excessive irritability of the nerve cells that regulate vital processes and hence are likely to derange such processes in ways unfavorable to the survival of the organism.

[4] *Ibid.*, p. 224.

e. In the process of oxidation in the organism certain waste products are formed which, if retained, induce fatigue. To facilitate their removal and allow for recuperation, sleep and good ventilation are essential.

2. The ultimate source of the energy of all living things is sunlight.
   a. Green plants combine such absorbed simple substances such as carbon dioxide, water, and nitrates to make sugars, starches, oils, proteins, and other materials. The energy for this process is furnished by the sunlight acting through the chlorophyll.
3. Microörganisms are the immediate cause of some diseases.
   a. The transfer of microörganisms from infected to noninfected individuals is prevented by (1) destroying them, (2) preventing the infection of carriers, (3) disinfection or destruction of carriers, (4) retarding the multiplication of infecting organisms through conditions inimical to their life, (5) establishment of immunity in individuals subject to infection.
   b. Microbes differ in their resistance to adverse conditions. Certain of them escape such conditions by forming highly resistant spores which survive them.
4. All organisms must be adjusted to the environmental factors in order to survive in the struggle for existence.
   a. Since other organisms constitute an important part of the environment of every living thing, there is a complex web of life and an interdependence of organisms, producing a balance of nature which man is prone to upset and which he is forced to restore by artificial means.
   b. Man must protect those plants and animals which he has pampered by his care under domestication (1) by cutting off the food supply of their natural enemies and competitors, (2) by preventing the reproduction of natural enemies and competitors, and (3) by direct destruction of these organisms.
5. All life comes from previously existing life and reproduces its own kind.
   a. In the higher forms of life the new organism usually starts as a fertilized egg.
   b. Unit characters are usually inherited as such and are determined by genes carried in the chromosomes.
   c. Corresponding maternal and paternal genes go to different daughter cells in the reduction division, so that characters associated in one parent often separate and combine with those from the other parent in the offspring.
   d. In some cases a character is determined not by a single gene but by a combination of two or more genes, in which case the character is not inherited as a unit; the factors are inherited.
   e. Genes that lie in the same chromosome move together in the reduction division, so that characters which they determine may be linked in inheritance.

   f. Some apparent exceptions to these principles are due to crossing-over. The greater the distance between any two genes in one chromosome, the more often they will separate if the chromosome breaks and part of it adheres to another chromosome.

6. Animals and plants are not distributed uniformly or at random over the surface of the earth, but are found in definite zones and in local societies.
   a. These zones are separated on the large scale by such more or less impassable barriers as oceans, mountains, deserts, and broad and deep rivers.
   b. Locally, societies are separated more commonly by variations in the moisture content of the soil, its chemical composition, by differences of light intensity and the distribution of food materials.
7. Food, oxygen, certain optimal conditions of temperature, moisture, and light are essential to the life of most living things.
   a. Frequently undesirable organisms, such as disease germs and insect pests, may be destroyed by denying them one or more of these essential factors.
8. The cell is the structural and physiological unit in all organisms.
9. The more complex organisms have been derived by natural processes from simpler ones, these in turn from still simpler, and so on back to the first living forms.

Principles in Chemistry

The Committee on Science Teaching submits the following as principle for the area of chemistry:[5]

1. To give pupils a broad genuine appreciation of what the development of chemistry means in modern social, industrial, and national life.

2. To satisfy the natural interests in the things and forces of nature with which men are surrounded and with which they must deal; to give information which is interesting, purely for its own sake.

3. To provide opportunity for the student to become acquainted with the application of chemistry to industry for the purpose of educational and vocational guidance and possibly to furnish a beginning of vocational training.

4. To develop such broad concepts and natural laws as the ultimate composition and indestructibility of matter, nature of chemical composition, interrelation of chemical elements, etc., to the end that science and reality may function in place of superstition and uncertainty in explaining natural phenomena.

5. To contribute such specific ideals, habits, and concepts as those of accuracy, achievement, persistency, open-mindedness, honesty, cause and effect, which are essential to the study of science.

[5] *Ibid.*, p. 257.

6. To develop system, order, neatness, and possibly other attributes, to the end that they shall function in the ordinary affairs of life.

7. To afford in some measure an opportunity to show the importance of scientific research and to stimulate the spirit of investigation and invention on the part of the student.

8. To give to children full opportunity to indulge in the playful manipulation of chemical material, in order that they may explore the world of reality as widely and deeply as possible.

9. To provide opportunity for acquaintance with such applications of chemistry in public utilities, in order that the student may more adequately fulfill the duties of citizenship.

10. To provide opportunity for acquaintance with such applications of chemistry as contribute to the maintenance of health of the individual and the community.

11. To provide opportunity for acquaintance with the elementary laws of nature which aid in understanding those citizenship problems which arise in connection with such topics as pure foods, utilization of waste products, elimination of smoke, etc.

12. To make pupils able to read more intelligently and with greater interest, articles on chemistry in magazines and in books dealing with science in a popular manner.

13. To give such training as will result in increasing respect for the work of recognized experts.

These statements are more in the nature of general objectives which should be achieved to a certain degree during a high school course in chemistry, rather than generalizations. Generalizations in chemistry should be stated in the following manner in order to coincide with the previous pattern:

1. All matter is probably electrical in nature.
   a. The properties of different elements depend upon the number and arrangement of the electrons, protons, and neutrons in their atoms.
2. Matter and energy cannot be created or destroyed; it merely changes its form.
3. Chemical and physical changes are manifestations of energy changes.
4. Chemical changes are accompanied by energy changes.
   a. If an equilibrium is disturbed the reaction moves in the direction in which there is less stress.
5. Chemical and physical changes are manifestations of energy changes.

The above principles are a sample of the type of generalizations which can be formulated and do not constitute a complete set by any means. A more complete set of principles is presented on pp. 94–95.

Principles in Physics

A functional and more complete list of generalizations in the area of physics may be stated in the following manner:[6]

1. The sun is the chief source of energy for the earth.
2. Matter and energy cannot be created or destroyed, but may be changed from one form to another.
3. Units of time are defined by the earth's movements in relation to the sun.
4. Distances in space seem incredibly great when compared to distances on earth.
5. Chemical and physical changes are manifestations of energy changes.
6. Sound is caused by waves which are produced by a vibrating substance and which can affect the auditory nerve of the ear.
7. Gravitation is the attractive force which influences or governs the movements of bodies.
8. Machines are devices for accomplishing useful transformations of energy.
9. Any machine, no matter how complicated, may be analyzed into a few simple types.
10. All matter is probably electrical in structure.
11. The kinetic energy of the molecules determines the physical states of matter.
12. The gravitational attraction between the earth and a mass of unconfined gas or liquid causes the pressure of that gas or liquid.
13. Liquid or gas pressure is exerted equally in all directions.
14. Chemical changes are accompanied by energy changes.
15. A change in the rate of motion, or direction of motion of an object requires the application of an external force.
16. Radiant energy travels in straight lines through media of uniform density.
17. Electricity is a form of energy that results from disturbing the position of the regular paths of electrons.

The foregoing lists of principles for biology, physics and chemistry may be helpful to the science teacher in preparing courses of study in each of the respective sciences. The modern concept of democratic school administration gives the science teacher an opportunity to formulate the curricula which will guide them in directing the learning of secondary school youth. Science teachers are expected to participate effectively in science curriculum construction as a part of their regular duties.

[6] *Ibid.*, p. 250.

ANALYSIS OF OBJECTIVES

Undergraduate students of education and beginning teachers appear to experience considerable difficulty in making a philosophy of education functional in the daily teaching activities. The general aim of education, aims, and general objectives seems to remain ethereal and far removed from the daily thinking of the average classroom teacher. This state of affairs probably may be due to a lack of understanding the broad and penetrating meanings of these objectives. As a result they have become merely a series of high-sounding phrases and words which have no place in the classroom.

It is possible to trace the contributions of each level of objectives to the ultimate aim of education. Beginning with specific objectives of a unit in general science entitled "Knowing the Earth," the specific objectives may be: (1) to know how the earth's surface changes; (2) to know how the earth is a storehouse; and (3) to know how we keep track of time and space on the earth. As the pupils go through the learning experiences which enable them to achieve these specific objectives, other concomitant learnings take place which we may call the general objectives. These objectives may be interests, skills, attitudes, ideals and habits. Because of the attainment of these general and specific objectives, to whatever the degree, these pupils will be brought closer to the ideals and aims of education whether they be the Seven Cardinal Principles, the aims proposed by the Progressive Education Association (meeting the needs of adolescents in the areas of living), or any other kinds of aims. Carrying this still further to the general aim of education, "Efficient Participation in a Democratic Social Order," we find that each child has advanced a step closer to this ideal.

These broader outcomes which we consider as aims and general objectives, to whatever degree they may be achieved, are the more permanent phases of learning. Interests, skills, and attitudes have a broader application in life and remain a permanent part of the individual long after specific facts and knowledge have been forgotten. This implies that greater emphasis in our teaching procedures should be placed on these areas of pupil growth.

Comparison of Objectives. It may be helpful to compare the objectives of science teaching as a whole with a science subject and a unit in science. For the entire area of science as a whole, one may employ the general aim of education, "Efficient Participation in a Democratic Social Order." The second category may be aims of science teaching which constitute the Seven Cardinal Principles: Health, Command of Fundamental Processes, Worthy Home Membership, Vocation, Citizenship, Worthy Use of Leisure, and Ethical Character. The third step may comprise the attitudes, interests, skills, habits, and understandings which are not directly measurable. And the fourth classification may include the specific learnings which are found in the study of the individual science subjects such as physics, chemistry, biology, geology, physiology, and physical geography, or the principles prepared by the Yearbook Committee.[7]

A set of objectives in a science subject such as general science may include the first three levels given in the preceding chapter comprising the entire area of secondary school science with a modification of the specific objectives. These may be stated as the unit themes of the individual units in the course such as "How Air is Necessary to Man," "Water is Indispensable to Human Welfare," "Living Things Depend Upon Each Other," and the like.

In the area of chemistry, the specific objectives may include, "Water is Composed of Hydrogen and Oxygen," "Sodium is a Typical Metal and Chlorine is a Typical Nonmetal," and "Sulphur and its Compounds Have Many Uses." Similar specific objectives may be given for the other secondary school science subjects.

For a unit in a science subject, the general aim of education may be used in order to maintain the "long view" in the classroom. The aims may include the Cardinal Principles which are directly ministered to by the learning experiences in the unit. For instance, a unit on "The Human Body" will minister to Health, Worthy Home Membership, Vocation, Worthy Use of Leisure, and Citizenship. This unit will minister to certain attitudes, interests, skills, and understandings. Finally, the measurable objectives may be achieved, such as "How the Human Body Functions," "How to Care for the Human Body," "How to Pro-

[7] See p. 50.

Science Objectives Compared

Science as a Whole	*Science Subject (General Science)*	*Unit in Science (Human Body)*
A	B	C
I. General Aim. Efficient participation in a democratic social order.	(Same as Column A)	(Same as Column A)
II. Aims. a. Meeting the needs in the areas of living: (1) personal, (2) personal-social relationships, (3) social-civic relationships, and (4) economic relationships	(Same as Column A)	Meeting the needs of (1) personal living, (2) personal-social relationships, (3) civic relationships
or		or
b. The Cardinal Principles: (1) Improved Health, (2) Command of Fundamental Processes, (3) Worthy Home Membership, (4) Vocational Efficiency, (5) Good Citizenship, (6) Worthy Use of Leisure, (7) Ethical Character.	(Same as Column A)	(1) Improved Health. (2) Worthy Home Membership. (3) Vocational Efficiency. (4) Good Citizenship. (5) Worthy Use of Leisure.
III. General Objectives. a. General knowledge and understandings. b. skills or abilities. c. attitudes. d. ideals and habits. e. interests.	(Same as Column A) plus Exploration	(Same as Column A)
IV. Specific Objectives. a. Information and understandings achieved through the study of: general science, biology, chemistry, physics, geology, physical geography, and physiology. or The Principles proposed by the Yearbook Committee.	Air Water Heat Weather The heavens Earth Living things The human body Communication Light Electricity, etc.	(1) How the human body functions. (2) How to care for the human body. (3) How to protect the human body from disease. (4) How to select reliable aid in keeping good health, etc.

tect the Body from Infectious Diseases,'' and ''How to Select Reliable Aid in Keeping Good Health.''

In tracing the growth and development of learning in these areas in reverse order, it is plainly seen that if a secondary school pupil masters the specific objectives, growth is achieved in the general objectives, and, finally, this composite growth results in achievement in the areas represented by the Cardinal Principles and the general aim of education.

METHODS OF DETERMINING OBJECTIVES. There are two major ways of determining the objectives of education, namely, the direct and the indirect methods. Under the direct method may be classified all types of scientific studies which are performed on the problem, and these studies use as their bases primary data and secondary data.

Studies which employ primary data in the solution of the problem of determining objectives may be termed job analyses and analyses of pupils' interests by means of the questions which pupils ask at different ages. In a job analysis study, the researchers go out into the activities of persons in society and actually find out what scientific information the adult person or children at different levels need in order to live successfully in modern society. A good example of this is a study made at Stephens College for women where the entire college curriculum is based upon a job analyses study.

Several thousand women in all walks of life were asked to answer questionnaires or were interviewed to find out the skills, interests, and knowledges which were required in order to successfully perform their daily tasks and general activities of life. This information was tabulated and organized and used as a basis for determining the objectives of all areas in Stephens College. In the field of science, it had determined which phases of knowledge concerning electricity, machines, energy, chemistry, biology, geology, and geography were necessary for their application in daily work.

In science, we have some studies which were carried out in industry to determine what industry expects of the employee as far as the field of science is concerned.

In order to determine what science knowledge children should

acquire, studies have been made of questions asked by thousands of children. A summary of these data helps to determine what information should be given to children in order to satisfy their curiosity. Objectives for any course in science, of course, are not determined by one of these means alone.

Under secondary data as a source of determining objectives we may classify studies which have made surveys of the science materials in newspapers and magazines; those which have analyzed and studied courses of study which were used; and those which have attempted to analyze the materials in textbooks used in the several fields of science. This type of guiding material is very helpful in determining the content and objectives of science teaching in all grade levels.

Other criteria which can be used for the determination of what our objectives should be in science teaching are general data such as college entrance requirements, reports and recommendations of committees, and opinions of experts. These criteria are not considered to be as reliable as the more scientific approaches, but it is necessary to supplement the more scientific means with the more subjective methods, as those before mentioned.

College entrance requirements have to be heeded, because if certain specifications are not lived up to, pupils are handicapped in their pursuance of certain knowledge. Opinions of experts used to be given a great deal more weight than at the present time, before the advent of the scientific approach to these problems. In the past, these experts tended to be highly scholarly professors teaching the college subjects and founded their judgments on ethereal and swivel-chair bases. As a result, such judgments tended to be of less practical character than was desirable. At present, we like to seek the opinions of people who have a background and understanding of child growth, educational psychology, and a broad educational philosophy based on these areas of information.

Recommendations of committees are considered more reliable than the opinions of experts or just a few such experts. The committees, such as the National Committee on Science Teaching, and the National Council on the Teaching of Science, are composed of many experts in the general and individual fields. It is generally accepted that two heads of equal ability are better than one of

the same ability; therefore, this can be extended to include that a committee composed of as many as a score of highly capable persons is more reliable and can make recommendations more authoritatively than those made by one person alone.

STUDY QUESTIONS

1. Why is it desirable for a teacher to know something about the aims and objectives of science teaching?
2. Select the statement of the general aim of education which you consider most functional.
3. What are the major aims of education as presented by the Committee on Curriculum Reorganization of the Progressive Education Association?
4. How may the objectives of science be organized for the purpose of better functional use in the planning of a teaching procedure?
5. Which type of objectives may be classified as aims? As general objectives? As specific objectives?
6. Evaluate the proposal of the Committee on Science Teaching of the National Society for the Study of Education to build science courses about broad ideas.
7. How are the objectives of science teaching selected?
8. Why are recommendations of committees valuable in determining a philosophy of science teaching?

ADDITIONAL PROBLEMS AND PROJECTS

1. Prepare a set of objectives for a science subject and for a unit in a science subject.
2. Discuss the relative merits of the objectives presented by the Progressive Education Association Committee on Curriculum and the Seven Cardinal Principles as presented by the Committee on the Reorganization of Secondary Education.

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5

The Science Curriculum

It is evident that the curriculum or content of the courses of study for any subject is an outgrowth of the objectives set forth for that subject. In science, the content of our courses comes from the objectives of science teaching which we have discussed in the previous chapter.

CRITICISM OF PRESENT PRACTICE

Present practice in the field of science teaching does not altogether fulfill the modern objectives of science teaching in many situations, although the whole field of science is highly functional in this day of scientific progress and almost wholly scientific environment. It is the feeling of progressive science teachers that science subjects in our secondary schools could be made more practical and functional than they are today. Great strides in the improvement of instructional materials have been achieved during the last 10 years, surpassing all other fields of secondary school instruction. The majority of science subjects are now organized on the unit plan and psychologically arranged so as to be presented from the pupil's point of view and related to the pupil's environment.

The subject of general science has achieved greater progress, possibly because the momentum began about 15 years ago when instructional materials were developed for the junior high school. In biology, in turn, there has been much more progress than in other science subjects. The specialized sciences, such as chemistry and physics, have lagged somewhat behind in this development, but they are beginning to show accelerated growth in this direction. In the physical sciences a few attempts have been made by authors to develop generalized courses in the upper secondary school grades. Progressive teachers are of the opinion that this is the type of science education which should be offered to our senior high school pupils.

It is apparent that many pupils who are exposed to, or have studied, the traditional physics and chemistry offered in the typical secondary school in the United States show very little transfer of this knowledge to their daily living. We find that after the study of these subjects the average girl makes no improvement or modification in her method of washing dishes or clothes, in general housecleaning, or in cooking. The functional course in science should definitely effect more efficient living on the part of not only the brighter pupils, but also of the average and subnormal children who have the ability to execute successfully the educational activities provided in our modern secondary school.

In the traditional science courses pupils are required to show proficiency in technical manipulations of symbols and to execute experiments which they are seldom able to apply in their daily lives. They learn the definitions of amperes, volts, heat of fusion, how to work problems in chemistry, the atomic weights, valances and symbols of scores of elements, but they learn very little about how to operate an electric or gas stove efficiently, how to carry out a simple replacement of a fuse in the home, or how to operate a washing machine, an electric mixer, or an electric toaster economically. In chemistry, we find that they learn very little about the workings of the automobile, how to purchase tires and lubricating oil; nor do they learn to understand the qualities necessary for efficient fuel. Very little is learned about why one should eat different types of foods, or how to make wise selections in the purchases of food at the grocery store.

Instructional materials fulfilling these objectives are being developed and the science teacher should utilize these materials as soon as they are acceptable in order to improve the functionality of science offerings. Caution should be exercised that these courses are not a poor imitation of the traditional course.

THE TEXTBOOK IN SCIENCE TEACHING

Even with the shortcomings of our present instructional materials in the field of physical sciences above the general science level, it is generally accepted that the best available textbooks are better for teaching than instructional materials prepared by the average teacher. People who are experts in the field of science teaching are

continually developing instructional science materials which are, upon their perfection, placed on the market.

The primary objective of teaching any subject is to effect maximum growth on the part of the learner. In the main, the elements which make up such growths are the following: acquisition of functional information, development of desirable character traits, interests and attitudes, development of skills in the acquisition of information, and the solution of problems, both immediate and ultimate.

In order to achieve this objective of growth, a technique of teaching which incorporates the knowledge regarding learning and growth processes must be employed. The first requisite is a scientifically constructed course of study, and second in importance are the room, teaching aids, and enrichment materials.

In many fields of instruction the textbook is the most efficient course of study attainable. The best examples may be found in the field of science which seems to be strides in advance of other fields of instruction in the matter of an adequate supply of textbooks and instructional materials. An investigation into the methods employed in achieving these instructional materials reveals that teacher-preparation of courses of study, syllabi, and teaching aids is almost as unintelligent as for the ordinary mechanic to build his own car. The modern textbook in science ranks very high in authorship, content, organization, and teaching aids; it is a result of skillful integration of (1) years of experience in the field of teaching the particular science subject, (2) years of scientific investigation, (3) the latest principles of educational psychology, and (4) a sound educational philosophy.

Most frequently, the energies and abilities of at least two authors have been pooled for the purpose of producing an improved product. This provides for expert counsel on the theoretical, practical, and factual phases which are necessary for the production of efficient instructional materials. A large proportion of the authors have had many years of teaching experience in the subject and have a broad and thorough background in subject matter, educational psychology, and philosophy of education evidenced by a degree of doctor of philosophy or its equivalent. In each of the fields of information specialists with a Ph.D. degree and exten-

sive experience more frequently than not coöperate in the production of a single textbook.

The content of the modern science textbook is based upon the best scientific information acquired to date by means of years of scientific experimentation as to the needs of pupils, interests of pupils of certain ages, needs of adult persons, and a composite of the best expert opinion. Results of investigations regarding the vocabulary suited to pupils of certain ages and the length of sentence and mode of construction suited to grade levels are likewise utilized. This procedure provides the most essential subject matter for contemporary growth of pupils.

The modern science textbook is psychologically sound in its organization. From the pupil's viewpoint the organization throughout is unitary in form, and the materials are presented in the form of problems. Other superior features reveal that the material is adapted to the age and grade of the average pupil; provisions are made for individual differences, increasing difficulty of content, individual problems, and use of the scientific method; and units are uniformly organized and adapted to seasonal sequence.

An exhaustive supply of teaching aids characterizes the modern science textbook. It is well supplied with demonstrations and experiments which are meaningful to the pupil, illustrations of all types, self-testing or learning exercises, workbooks, glossaries, teachers' manuals, pupil references, and the like, which make it possible for teachers of all abilities efficiently to care for individual differences. It is not intended that the teacher should be limited entirely to the use of one text, but it is economical for the teacher to use as many of these teaching aids as possible before spending time looking for additional suggestions elsewhere.

In view of the foregoing facts, it appears that time and energies expended by individual teachers and committees for the purpose of producing courses of study or syllabi is vain and utterly wasteful. For every hour expended by the average teacher in attempting to produce such instructional materials which are bound to be inferior, a scientifically constructed textbook or three workbooks of the same superior quality can be purchased. It would be far more economical to have these teachers spend this time and energy upon motivation, preparation, and enrichment materials,

which will effect better administration of the already scientifically prepared instructional materials.

This discussion has been devoted primarily to the field of science, but a large proportion of these principles can be applied to other fields of instruction and with increasing application as improved instructional materials become available.

SELECTION OF TEXTBOOKS. In view of the fact that a textbook is the primary tool of science teaching, it becomes a paramount responsibility of the science teacher to be able to select efficient textbooks. A textbook cannot be judged merely by thumbing through or glancing through it. It is necessary to evaluate this piece of instructional material in the light of several criteria: (1) content, (2) organization, (3) teaching aids, (4) educational rank of the author, (5) mechanical make-up, (6) extent of use, and (7) cost.

The most important criterion in selecting a textbook is, of course, the content. The content should be such as to meet the needs of the children at the relative age levels. These needs include interests and proper vocabulary for the respective grades. There have been many scientific studies with the object in view of determining the proper content. The second criterion is the form of organization. The textbook should be psychologically organized; that is, organized according to the best-known facts about the psychology of learning. A third criterion might be the teaching aids which are provided correctly in a textbook. The good textbook which makes an efficient tool should include well-developed sets of learning exercises that provide for individual differences in the form of suggestions for projects, reports, and the like.

A fourth important criterion in the selection of a textbook is the educational rank of the author. In many cases, this might be more important than other features of a textbook if one knows the qualifications and abilities of the author and his reputation. Frequently, it may be wise to accept the judgment of an outstanding author or a group of authors of science textbooks, rather than to attempt to evaluate the textbook or instructional materials according to the reliability of the content and the form of organization, about which the average teacher knows very little in comparison with that known by such outstanding authors. Authors may be

ranked, first, according to the degree to which they are investigators in the subject field of science education; second, to the extent to which they are actually teaching in the field of secondary school science; and, third, to the extent to which they are authorities in their fields or to the extent to which they are scientists. Degrees and honors achieved by authors are reliable and objective criteria of the possible ability of such a person.

There are many authors who have conducted extensive experiments in the field of science teaching involving 10 to 20 years of intensive effort. It is very important that at least one author of a science textbook be actively engaged in teaching in the secondary school field because it is very easy for persons not actively engaged in the field to become highly theoretical and impractical. Authors who have earned the Ph.D. degree in the field of science teaching and in addition have had considerable study in psychology and educational administration, should provide the persons of highest caliber for the production of science instructional materials. At present, few individuals attempt to produce a textbook without the aid of at least one or two other co-authors who are specialists in certain other fields in the area of science teaching, such as the fields of educational philosophy, curriculum construction, and in the field of science itself.

Other important criteria in the selection of a textbook may be the mechanical make-up, cost, literary style, and teacher helps.

Under the item of mechanical make-up, one may consider features such as the artistry of cover, durability of binding, quality of paper, size of book, size and legibility of type, length of line, and artistry and quality of cuts. Under the heading of literary style, one may include the attractiveness of the title of the book, interest appeal to the pupil, understandability by pupils, and adaptability of vocabulary to the proper level of pupils. Under teacher helps, one may place the Preface, which outlines the author's purpose. Glossaries, teacher references, illustrative units, table of contents, comprehensive indexes, and comprehensive teacher manuals are important in a textbook. The matter of cost is important, too, yet it is an item which is quite well stabilized because of the competition in the production of instructional materials. Other things being equal, the choice of text may favor the

one of lighter weight for convenience in carrying, especially for pupils who have long distances to walk.

Extent of use is a practical criterion which may be used to advantage. If the book is used by progressive school systems throughout the nation, it is a fairly reliable endorsement of the textbook's efficiency. A statement which was often made by a late outstanding educator, "People wabble but they usually wabble right," is a pragmatic maxim. Publishers frequently publish the names of schools and school systems which are using certain textbooks as a basis for their science courses.

A sample of a score card for rating textbooks is as follows:

THE EVALUATION OF SCIENCE TEXTS[1]

These texts have been evaluated on the basis of the scores in the *first column.*

The theoretical perfect score for a text 1000

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______

		1	2	3	4	5	6
1. Educational Rank of Author	50						
A. As investigator in special field of ed...	20						
B. As teacher in special field of ed.......	15						
C. As scientist, degrees and honors......	15						
2. Mechanical Make-up and Cost..........	100						
A. Durability of cover.................	5						
B. Artistic cover.....................	5						
C. Durability of binding..............	10						
D. Quality of paper..................	15						
E. Size of book......................	5						

[1] Hunter, George W.: "Science Teaching," New York, American Book Co., 1934, p. 253.

		1	2	3	4	5	6
F. Size and legibility of type	10						
G. Length of line	5						
H. Artistic quality of cuts	10						
I. Distinctiveness of cuts	10						
J. Size and clearness of footnotes	5						
K. Cost	20						
3. Psychological Soundness	300						
A. Organization throughout from pupils' viewpoint (psychological)	100						
B. Unitary organization	40						
C. Materials presented in problem form	40						
D. Uniform organization of units	5						
E. Seasonal or psychological sequence of units	10						
F. Materials adapted to age and grade of average pupil	20						
G. Provision for individual differences	20						
H. Provision for increasing difficulty	5						
I. Provision for individual problems or projects	10						
J. Fundamental generalizations developed through use of induction	20						
K. Provision for use of scientific method	30						
4. Subject matter	250						
A. Based on environment, interests and activities of pupils	70						
B. Socially worthwhile	50						
C. Accuracy of factual material	30						
D. Practical applications	25						
E. Essential topics included	40						

		1	2	3	4	5	6
F. Amount of supplementary material adequate	10						
G. Fundamental generalizations presented	15						
H. Number of review summaries given	10						
5. Literary Style	110						
A. Title arresting	5						
B. Interesting to pupil	25						
C. Understandable by pupil	20						
D. Clear and concise	15						
E. Has interpretive values	20						
F. Correlates subject with others in curriculum	10						
G. Vocabulary adjusted to pupils	15						
6. Learning Exercises	140						
A. Sufficient number of demonstrations and experiments meaningful to pupil	15						
B. Laboratory exercises 1. Adequate in amount and suggestive to pupil	15						
2. Practical applications	10						
3. Developed in problematic form	10						
C. Illustrations 1. Adequate in size, number, and quality	10						
2. Line drawings for demonstrations	5						
3. Half tones of natural objects	5						
4. Legends used as learning devices	15						
5. Maps, graphs or diagrams	10						
D. Suggestions for making organization reviews and summaries							
1. Testing devices adequate	15						

		1	2	3	4	5	6
2. Pupil references adequate	10						
3. Glossary	5						
4. Separate workbook or pupil's laboratory book	15						
7. Teacher's Helps	50						
A. Purpose of author indicated in Preface	3						
B. Purpose of author constantly developed in text	7						
C. Glossary	5						
D. Teacher's references	5						
E. Illustrations used as teaching units	5						
F. Adequate table of contents	5						
G. Adequate index	5						
H. Separate teacher's manual	15						
Efficiency	1000						

The Criteria of Organization of Content. After the content for a subject in science has been decided upon, the organization of this content is very important in determining the effectiveness with which it may be transferred to the pupils. It may be organized both according to the psychological aspects of the human learner and according to the form, such as whether it is on the topical, problem, or unit plan. A psychological organization unquestionably is the most important criterion of organization. Under psychological organization one would consider whether the material is organized throughout the textbook from the pupils' point of view, adapted to seasonal changes, and suited to the proper age level of the pupil. Provisions for individual differences, arrangement according to increasing difficulty, and provisions for the use of the scientific method and development of the scientific attitudes are mandatory. Modern instructional materials in science are meeting these criteria of organization to an increasing extent.

At present the unit plan is considered the most adaptable plan of organization because under it individual differences can be cared for with less difficulty, and it employs the fundamental principles involved in modern educational psychology. This plan affords a unified and related presentation and participation by the teacher and pupil, respectively, in learning experiences. An overview of the whole unit is possible at the beginning in order that pupils have a perspective of what they plan to achieve or in what direction they are going. During the assimilation period it permits the use of all techniques and methods which are suitable for the type of learning at hand whether it be reading, experimenting, drawing, or any other activity which would effect learning on the part of the pupil. After the pupils have mastered the content of the unit to a reasonable degree, a mastery examination may be administered in order that the amount of measurable learning may be determined. New materials are not attempted until the previous unit has been organized in the pupil's mind. This prevents the injection of discordant and unrelated materials.

The problem plan of organization may be used as a part of a broader unit plan of organization. In such organization, the items in the unit would be formulated in the formal unit problems. Many instructional materials in science lend themselves entirely to the problem organization, for example: "How heat may be controlled for use in our homes," "How electrical energy is used in the home," or "How machines may be of service to man."

The topical form of organization seems gradually to be losing ground, primarily because it tends to present instructional materials in compartmental and unrelated patterns. This lends itself to nonfunctional learning which consists of learning unrelated facts more or less by rote. According to psychology, the brighter pupils are able to integrate and relate separate facts into a functional whole, but the average or below-average pupils cannot. For these pupils, it is necessary to do the integrating and make the applications as the facts are being learned.

There seems to be no differentiation as to form of organization between the different science subjects offered in the secondary schools, namely, elementary science, biology, chemistry, physics, and probably physical geography. The unit plan of organization

seems to be as valuable in one subject as in another. It is true, however, that up to the present time this form of organization has been more prevalent in the more elementary subjects in the field of science, such as elementary science and biology. This does not mean, however, that the unit plan of organization is not just as applicable in chemistry and physics. The reason for the lack of development in the more advanced sciences is due apparently to lack of effort in the preparation of these materials. In due time, instructional materials organized on this plan will be as common as in the other areas before mentioned.

The level of the school structure seems to make no differentiation between the needs in form of organization. This applies also in the subject fields; that is, the unit form of organization is more prevalent in junior high school subjects than in many of the senior high school subjects. This development is primarily due to the lack of determined effort for the development of this more desirable form of organization. It is the author's belief that this functional form of unit organization will gradually permeate the entire area of the secondary school program.

THE SCIENCE CURRICULUM IN THE JUNIOR HIGH SCHOOL

There are two types of junior high school organization. One type is referred to as "The Reorganized Type," including the seventh, eighth, and ninth grades; and the other is the "Unorganized Type," wherein the eight-four plan is in operation.

In the three-year junior high school organization, the general practice is to offer science in each of the three grades. The amount offered varies with different schools. In some cases, two periods a week of science studies are provided in the seventh grade, three periods in the eighth grade, and five periods a week in the ninth grade. Very few schools attempt to offer five periods of science in each of the three grades. Frequently, the content involving the physical sciences is included in the courses of study of the seventh and eighth grades, and the biological area is taught in the ninth grade. A more desirable plan is to confine the content of the entire junior high school program to a definitely integrated science course giving some time to the entire field in each and every grade. At the

present time, several junior high school science series on this plan are available. This permits a comprehensive course in functional biology in grade ten.

In schools which are "unorganized," very little science is offered in the seventh and eighth grades. The content of this type of offering necessarily must be different from the ninth grade course in a reorganized school. The textbooks and approach should be different.

In general, the objectives of junior high school science teaching may be classified under two major heads: (1) To interpret environment, and (2) exploration.

Children at this age are extremely curious about environmental factors and a course in science should serve to explain and answer the problems that rouse their interest. Under current practice, specialized science courses are offered, and the general science course should serve to give the pupils an idea as to the content of biology, chemistry, physics, geography, etc., which they will have an opportunity to choose for study in the senior high school. According to the best opinion on science education, these specialized courses are not considered the right type for secondary school education, but until generalized courses are provided for the entire secondary school program, the exploratory phase of general science should be maintained.

SELECTION OF CONTENT FOR JUNIOR HIGH SCHOOL SCIENCE. The Committee on Science Teaching of the National Society for the Study of Education proposes criteria for the selection of junior high school science which are in harmony with the modern philosophy of education. The criteria are as follows:[2]

1. The content shall be chosen on the basis of its possible contribution to the objectives set forth in a preceding section of this book.

2. Subject matter shall be considered primarily as a means to an end and not merely as something to be remembered.

3. The course shall consist of a variety of physical and mental activities that shall lead to those knowledges, skills, interests, and attitudes essential to desirable mental and practical adjustments to the environment.

4. The content of the course shall bear direct significance to life's problems and activities.

[2] National Society for the Study of Education: Thirty-first Yearbook, Part I, Bloomington, Illinois, Public School Publishing Co., 1932, p. 208.

5. The order of difficulty of the learning activities shall be such that pupils through reasonable effort may gain the satisfaction of accomplishment.

6. The learning activities shall call for experiences with the materials and forces of everyday life.

7. The learning activities shall be of such a nature that pupils may be interested in undertaking them and in carrying them to completion under the motivation and helpful guidance of a well-trained teacher.

8. The activities shall be such that they lead to the comprehension of the elementary generalizations of science that have important social implications.

9. The activities shall include abundant opportunities to apply the acquired knowledges, skills, and attitudes in life situations.

10. The activities, by their nature and order of difficulty, shall afford opportunity for the exercise of the creative abilities of youth and for the joy, romance, and adventure that discovery, invention, and self-production in science afford.

11. The activities shall be objective enough to be attainable and to make possible the determination or measurement of the attainment desired.

12. There shall be some activities that afford pupils means of judging and measuring their progress in the more specific learning activities.

13. Some activities, at least, shall be of such a nature that they may be organized into problems identical with the problems of life.

14. The activities shall call for direct, concrete experiences so far as possible, but vicarious experiences that are educative should not be neglected.

Tentative principles of organization recommended by the Committee are:[3]

1. The course shall be organized into units, each of which shall be related to some significant aspect of the environment.

2. The unit shall be essentially a major problem of everyday life to which science may contribute the intelligent basis for human adjustment.

3. Each unit shall include only a few principles or generalizations of science.

4. Each unit shall be divided into subordinate problems to facilitate learning by pupils.

5. The continuity of the units shall be such that the entire course develops a sequential story of man's understanding of, and adjustment to, his whole science environment.

6. The organization, in part at least, shall be in the form of problems or projects to insure education in problem-solving, which is the nature of science.

7. There shall be relatively few units, in order to insure that pupils are brought to the understanding of the larger relationships of the facts and principles of science rather than to the mere memorizing of detailed facts.

8. The units shall be so organized that the conceptions of science and their

3 *Ibid.*, p. 209.

social implications, once learned, shall be used in new relationships in later units.

9. The interrelationships of generalizations and their social significance shall be brought to the attention of pupils by abundant cross references and "cross exercises."

10. Not only shall generalizations be developed in each unit, but there shall also be abundant opportunities to apply the generalizations in the interpretation of novel problems and novel phenomena.

11. In so far as possible, the units and their study materials shall be arranged and organized in such a way that the succeeding units will call for the understanding of larger and larger relationships and conceptions, will contain progressively difficult activities, and will arrive at more and more comprehensive adjustments.

12. There shall be provided in each unit enough activities to insure accomplishment of the objectives by pupils of different interests and capacities.

13. In general, the units and the subordinate problems within each unit shall proceed in line with the scientific methods of problem-solving; that is, (a) from sense perceptions of materials, forces, or phenomena to the formulation of ideas, to the testing of the hypotheses, to the tentative conclusions, and to the application of the conclusions in life situations, or (b) from principles or generalizations to the interpretation of specific situations.

14. The distribution of time and emphasis to the various units shall be determined by the total, functional, social value of the unit, its "teachability" and "learnability," the teacher's and pupils' interest in the unit, the local significance of the unit, and its value to other units of the course.

15. The entire set of units shall be so formulated that the pupil will have revealed to him the kinds and nature of the major fields of science.

16. The laboratory work shall be included as an integral part of problem-solving and shall, therefore, have the characteristics of experience-getting work rather than of illustrative or confirmatory work.

17. Historical and biographical content shall be introduced when and where it will aid in the understanding of the concepts developed and of their social implications and in the attainment of the human adjustments sought.

18. Subject matter shall be so arranged that it will be a means to the solution of problems and not an end in itself.

19. In so far as possible, the materials and activities shall be organized around the pupil's life but shall project the pupil into the problems of adulthood.

20. The organization shall be such that it will lead to the attainment of the immediate and ultimate objectives.

Curricular Studies in Junior High School Science. Such studies may be classified into several areas: (1) children's interests; (2) analysis of current literature; (3) analysis of textbooks and courses of study; and (4) analysis of life activities. Only a few

of the more important studies in this field will be summarized here.

Children's Interests. Pollock and Curtis are two investigators who have made an extensive study in the area of children's interests. In 1924,[4] Pollock published a study which attempted to determine the interests of eighth grade children in Columbus, Ohio, in the area of science and required children to list questions which they would like to have answered. The 3,500 questions received were classified and ranked in the order of frequency mentioned.

Curtis[5] included interests for adults at the same time that urban children's interests were determined, and his second study[6] procured the same information from rural areas. A total of 3,330 questions from pupils and 3,232 from parents were received and tabulated for the first study. The second study included 32 high schools in small towns of Michigan with a median population of 309. These results show considerable agreement between the scientific interests of children and adults. Among the first 10 topics on each list were electricity, stars, radio, sun, moon, and the earth. Other common topics were planets, lightning, plants, and animals. Curtis found the correlation to be from .62 to .72 between the ranks of the same topic in his first and second studies and Pollock's study. A surprising similarity was found between urban and rural science interests.

Two more recent studies worthy of mention are those by Boomsliter and Nettels. The former study was published in 1936, and the latter in 1931. Miss Boomsliter[7] analyzed 10 textbooks in general science from which she formulated a list of 703 different items

[4] Ohio State University Educational Bulletin, *3*: 3–6, 1924. Abstracted in Curtis, "A Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1926.

[5] Curtis, F. D.: Some values derived from extensive reading of general science, *Contributions to Education,* No. 163, Teachers College, Columbia University, 1924, pp. 27–40. Also in Curtis, "Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools," Philadelphia, The Blakiston Company, 1926, p. 326.

[6] Curtis, F. D.: A study of the scientific interests of dwellers in small towns and in the country, *Peabody J. Educ., 5*:22–34, July, 1927. Also in Curtis, "Second Digest of Investigations in the Teaching of Science in the Elementary and Secondary Schools," Philadelphia, The Blakiston Company, 1926, p. 343.

[7] Boomsliter, Alice C.: "A Selection of General Science Textbook Material to Meet the Needs of Junior High School Children in an Industrial Community," Unpublished M.S. thesis, West Virginia University, 1936.

or topics. This list was submitted to seventh and eighth grade pupils and their parents. The subjects were asked to check each item they would like to know something about or needed to know. In order of rank, these topics were health, household arts, gardening, manual arts, general interests, and pure science.

Nettels[8] made a study of children's science interests and also those of parents covering the two groups of 1,000 each. In general, the findings of this study were almost identical with those of Pollock and Curtis. Nettels also studied the relation of children's interests to sex and to ability. With some variance according to ability boys generally ranked chemistry, earth, electricity, animals, aviation, and astronomy in the order named, while girls like animals, plants, stars, the human body, insects, and birds, respectively. This indicates that emphasis in treatment for the different sexes and different levels of ability may be desirable.

In a study of the science needs in the middle Appalachian regions, Feaster Wolford investigated the scientific interests of children as revealed by questions about scientific topics, and the reading interests of pupils as revealed by an analysis of newspapers and magazines which they read. The results reveal that these people were more interested in their immediate than in their remote surroundings. The greatest interest seemed to be in those things which concern living in the region. People were considerably interested by what they had already studied in eighth-grade science classes, and many questions asked dealt with the theoretical science of things rather than the practical.[9]

Fitzpatrick made a study in which he attempted to determine the probable reliability of interest studies. Pupils of several grade levels were employed for the purpose of determining the reaction to 100 items which were suggestive of science interests. Some of the reactions were taken 15 minutes apart and some were taken

[8] Nettels, C. H.: Science interest of junior high-school pupils, *Science Education, 15*: 219–225, 1931. Also in Curtis, "Third Digest of Investigations in the Teaching of Science in the Elementary Schools," Philadelphia, The Blakiston Company, 1939, p. 234.

[9] Wolford, Feaster: Unpublished Ph.D. Dissertation, Cornell University, 1935. Abstracted in Curtis, "Third Digest of Investigations in the Teaching of Science in the Elementary Schools," Philadelphia, The Blakiston Company, 1939, p. 47.

three months apart. Analysis showed that the general inconsistency of the testimony made any conclusion regarding science interests on any grade level, or the group of subject-matter material desired, a dubious matter.[10]

Analysis of Current Literature. Studies in this area are relatively few for junior high school science, but several have been published for senior high school subjects. Two of the more important studies may merit summarization.

Curtis[11] analyzed 2,783 magazine articles with respect to science content, consisting merely of a phrase or a sentence or two. The results of this study show the need for the broadest possible training in general science as the basis for understanding and enjoying as much as possible the science information found so abundantly in the public press. Some of the important facts are as follows:

1. Only 13.7 per cent of these articles contained scientific information which requires no background.

2. Only 1.2 per cent gave definitions of terms to facilitate understanding of further information contained in the article, even though more than half of the articles contained scientific or technical terminology.

3. About half the articles analyzed as to scientific content contained a term or fact incidentally included. The articles as a whole were devoted to some interest other than scientific, but the full significance of the article was to a significant degree dependent upon the knowledge of the science content.

4. Courses in general science should provide definite training in discriminative reading of newspaper articles containing scientific discussions in order that pupils may progress in the development of scientific attitudes while achieving entertainment and information, and should stimulate pupils to use the added information they

[10] Fitzpatrick, F. L.: "Science Interests," Bur. Publications, Teachers College, Columbia University, New York, 1936. Also in Curtis, "Third Digest of Investigations in the Teaching of Science in the Elementary Schools," Philadelphia, The Blakiston Company, 1939, p. 238.

[11] Curtis, F. D.: "Some Values Derived from Extensive Reading of General Science," Contrib. to Education No. 163, Teachers College, Columbia University, New York. Also in Curtis, "Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1926, p. 318.

achieve as a foundation for growth in broader knowledge which leads to greater pleasure from reading in addition to the possible practical value.

5. More than a majority of the newspapers having scientific content contained scientific information ranging in complexity from the very simple to the extremely complex and technical.

6. About a fifth of the articles furnished advice of a scientific nature, and about 1 out of every 20 could be judged as giving definite instruction.

7. Completely and carefully organized discussions of topics and phases of science comprise about one sixth of the articles, while about one fifth are semi-organized.

8. Articles containing biological information equalled those comprising the physical sciences, indicating that science courses of study should contain a more equitable proportion of biological material comparable with that now given to the natural and physical sciences. This is not true in the present courses of study where the physical sciences receive the greatest measure of attention.

9. Pupils probably should have special emphasis on scientific terms because Curtis found 962 different scientific terms in 630 articles.

Searle and Ruch[12] made a study of science articles published periodically during a 10-year period in such magazines as *The Literary Digest, The American, The Review of Reviews, Current Opinion, The National Geographic, The Atlantic, Scribner's, The World's Work,* and *The Saturday Evening Post.* Also, articles in scientific magazines were compared with them. It was found that the magazines studied contained articles on the major topics of each of the high school science subjects, though the quantity found on a topic under each subject varied slightly. A large majority, or 62.2 per cent, of this space was devoted to biology. Physics ranked second, or 26.3; and next in order were chemistry, 5.1; general topics, 4.0; and agriculture, 2.4. In looking over the table giving the detailed topics, the percentage of space devoted to each

[12] Searle, A. H.: A study of science articles in magazines, *School Science and Math., 26*: 389–396, 1926. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 339.

indicates that these articles cover pretty well each area of general science.

A very small percentage of our secondary school pupils have an opportunity to study more than one of the specialized sciences; therefore, it is very important that a comprehensive course in general science be offered in order to give these people a background that will enable them to appreciate and understand current literature.

Analysis of Textbooks. This type of curriculum study was very popular in the 1920's and has greatly helped in a more scientific determination of the textbook content for junior high school science. Several studies have been made by Webb, Iler, Klopp, Heiss, Arnold, and Davis. One of the more recent is by Ira C. Davis[13] who made a study for the purpose of determining the subject matter topics discussed in the textbooks of general science which were most widely used in the State of Wisconsin. Davis found that there was a high degree of uniformity in content among textbooks for the units on air, water, heat, weather and climate, light, magnetism and electricity, energy and machines, plants, the human body, and foods; fair agreement in the units on sound, the solar system, and rocks and soil, and very little in the units on animals and clothing. The results of this study show definitely that leading textbooks in general science do agree on subject matter, and have achieved integration and continuity in the place of unrelated mixtures of science. General science ranks below physics in agreement of content with chemistry and biology, lacking more in this desirable characteristic.

This study shows that there has been a great deal of improvement in the content and organization of general science books as the result of persistent curriculum study during the 10 years prior to this study. It is reasonable to conclude that the progress since 1931, when the investigation was published, has continued to be great.

Comprehensive Study. A few comprehensive studies have been attempted which tend to combine results of the individual studies

[13] *School Science and Math.*, *31*: 707–714, 1931. Also in Curtis, F. D., "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 66.

of a narrower scope. The most outstanding of these is one by Francis D. Curtis.[14] He combines the results of four textbook analysis studies by Howe, Webb, Weckel, and Miller; six analyses of scientific interests reported by Pollock, Washburne, and Curtis; three published reports of analysis of magazines and newspaper science reported by Finley and Caldwell, Searle and Ruch, and Curtis; the study of consumption of food, shelter, clothing and fuel by Harap; and the report of the Cleveland Schoolmasters' Club. From an analysis of these several studies and courses, Curtis secured 1,850 subject matter topics organized and placed in a table containing major unit topics and minor subtopics with the attendant percentage values. In studying this table it is possible to find quickly the topics which are given higher values. For example, the major topic of air was given a value of 92.9; its occurrence, 49.1; extent of the atmosphere, 51.0; composition of the air, 76.3. This study has been used to a considerable extent as a basis for writing textbooks and courses of study in general science.

Evaluation of Three-year Sequence. A few studies have been made to determine the relative efficiency of the three-year junior high school science sequence, as compared with the one-year extensive study of science in the ninth grade. A summary of the more significant investigations may be of value. Carpenter[15] attempted to study the influence of general science study upon grades achieved in high school chemistry and physics, and to compare the three-year sequence with the one-year study of general science. The results in the final examinations of 411 pupils in physics and 664 pupils in chemistry were recorded. The results favored the three-year science program in the junior high school. Consistently higher median scores were achieved on final tests in physics and chemistry by the pupils who had studied general science for five or six semesters compared with those who had had less than five terms of junior high school science. The pupils who had studied general science

[14] Curtis, F. D.: "A Synthesis and Evaluation of Subject Matter Topics in General Science," Ginn & Co., 1929. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 92.

[15] *Science Education, 17*: 183–192, 1933. Also in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 68.

showed the same superior performance in chemistry and physics over those who had studied elementary biology.

In the second phase of the study, a high relationship was found between success in the specialized sciences and the number of semesters of previous general science study. A 5 per cent higher score was achieved by pupils who had studied the subject for five semesters than those who had studied science for four semesters, and a 10 per cent higher score than those who had studied the subject three semesters. It was found further that there was a definite increase in the scores of these general science tests from the seventh grade to the ninth grade; and ninth-grade pupils who had studied general science for four terms had 11 per cent higher scores than ninth-grade pupils who entered high school without previous training in general science.

Carpenter[16] made another approach to the evaluation of general science by attempting to find out whether the study of general science added to similar interest in other science courses and whether the influence for success in the study of chemistry and physics was greater as compared with the influence of biology. It was found that the pupils who had been oriented by a course in general science achieved from 1 to 10 points higher median test scores in physics and chemistry than those who had not studied general science previously. It was further shown that these pupils showed a larger percentage of improvement in physics and chemistry than they achieved in other subjects, such as English, Latin, and intermediate algebra. The results of the study seem to justify the conclusion that the gains in chemistry and physics are likely due to general science preparation. In addition, a larger proportion of general science pupils than biology pupils are found to continue advanced science study.

USE OF CURRICULAR STUDIES. Curricular studies of the type previously summarized serve as scientific bases for selection and organization of science content. Writers of texts in junior high school science find in these investigations authoritative guides for producing more efficient instructional materials. Results of these

[16] *Science Education, 14*: 589–599, 1930. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 129.

studies serve to help the science teacher develop a more adequate philosophy of education and more efficient teaching techniques.

THE TEACHING OF AVIATION

During World War II, because of necessity, military agencies stimulated a great deal of interest in aviation. Special aviation courses were introduced in the secondary schools in order to prepare youth for service in the air corps. An analysis of peacetime needs shows that the airplane compares with the automobile in importance. For this reason, it would seem more practical to integrate the study of aviation with other subjects. Integration of the aviation subject matter materials with the regular secondary school subjects will eliminate the necessity of retrenchment in other subjects to make room for these special subjects in aviation.

In the social studies, regulations regarding aviation and related topics included under Civil Air Regulations may be taught. Aerodynamics can be very effectively taught in a secondary school course in physics and the elementary phase of it in the standard general science course. Engines and power plants, usually taught as a separate subject in the training of aviators, lends itself readily to integration in secondary school courses in physics and chemistry. The aviation phase of meteorology can be effectively taught in courses in chemistry and general science; avigation, or aerial navigation, may be effectively integrated with courses in mathematics, especially algebra, geometry, and trigonometry. The addition of this subject to the traditional mathematics course units may serve also to make these subjects more interesting and functional.

STUDY QUESTIONS

1. What are the criticisms of the present science curriculum?
2. What science subjects have made the most progress in improvement of their curriculum?
3. How can the science textbook be justified as a basic course of study in teaching any science subject?
4. Give several reasons for taking great care in the selection of textbooks.
5. What are the most important criteria in the selection of a textbook?
6. Why is the score card method recommended in the selection of textbooks?
7. Name some practical but unscientific criteria which may be used in part in the selection of textbooks.

8. What are the objectives of junior high school science teaching?
9. What are the criteria for the selection of content in the junior high school?
10. What type of organization of content is considered most desirable for the junior high school level?
11. Give the results of studies in the area of children's science interests.
12. To what extent does current literature contain science information?
13. How have analyses of textbooks in science contributed to an improved curriculum?
14. Discuss briefly the comprehensive study made by Francis D. Curtis on the content of general science.
15. Evaluate the three-year scheme of science in the junior high school as compared with the intensive study of science in the ninth grade.

ADDITIONAL PROBLEMS AND PROJECTS

1. Select at least five science textbooks and score them on the score card found on page 71. This may be done in many ways. All the textbooks used may be the latest text in any one subject, may be an assortment of old and new texts, may be the latest in several science subjects, or any combination which will suit the interest and purpose of the student.
2. Present to the class a detailed report on a comprehensive curriculum study on the junior high school level.
3. Make a list of the units which should be included in a course in general science and make a list of problems which should be included in a unit in general science.

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6

The Science Curriculum (Continued)

THE SELECTION OF CONTENT IN SENIOR HIGH SCHOOL SCIENCE

The need in the field of senior high school science is the reorganization of content to meet the needs and interests of present-day life. If the objectives set forth by the Commission on Secondary School Curriculum of the Progressive Education Association are to be achieved, drastic changes are necessary in the content of chemistry and physics. Other science subjects ordinarily not taught in secondary schools should be included in order to provide functional science training for pupils in our secondary schools. It may be pertinent to state these objectives again: (1) teaching the needs of adolescence in immediate personal-social relationships; (2) meeting the needs of adolescence in social-civic relationships; (3) meeting the needs of adolescence in economic relationships; (4) teaching ways to encourage reflective thinking; and (5) meeting the needs of adolescence in the area of personal living.

In the area of personal living, we find the need for growth in personal health and self-assurance—to formulate a satisfying world picture, a workable philosophy of life, a range of personal interests, and esthetic satisfaction. In the area of immediate personal-social relationships, we find the need for increasingly mature relationships in home and family life, the need for successful and increasingly mature relationships in age mates of both sexes, and training in sex education. In the area of social-civic relationships, we find the need for acquaintance with the school and social community. In connection with economic relationships comes the need for emotional assurance of progress toward adult status, the need for guidance in choosing an occupation and for vocational preparation, the wise selection of goods and services, and the need for effective action in solving economic problems.

The average science teacher may not possess the capacity or training for organizing courses of study which will fulfill these requirements or be qualified to select prepared materials which are suitable for achieving these objectives.

THE CURRICULUM IN BIOLOGY

Selection of Content in Biology. Biology has kept pace with modern thought in education to a greater degree than have the subjects of physics and chemistry. The first step forward was the combining of botany and zoology in one course called biology. Since the earlier practice of giving separately a semester of botany and a semester of zoology was changed to a one-year course, modern authors have developed textbooks which integrate the two areas into one functional course. The popularity of the unit method of organization for science subjects may have been one of the greatest forces in stimulating this progressive step.

Relatively few curriculum studies have been made in the field of biology, the greatest number being in the area of the analysis of current literature. Finley and Caldwell[1] studied 17 full months' issues of different individual newspapers of varied types distributed throughout the country, and found a total of 3,061 articles on biology. Finley found that the most frequent topic was health, including diseases, hygiene and sanitation, health education, dietetics, drugs, first aid, and physiology. The topic ranking second was that of animals, which included their improvement and care, general interest, recreation and enjoyment, economic importance, conservation and propagation, diseases, life histories, and geographical distribution. Plants ranked third in popularity, including cultivation, forestry, gardening and horticulture, climatic influences, breeding and improvement, industrial uses, diseases, new plants, memorial planting, and conservation. A great deal of space was given to the discussion of food, regarding cost, shipping and packing, purity, production of food and national welfare, conservation and preparation of food. Other topics given a minor amount of space were nature, including education, recreational value, and

[1] Lincoln School of Teachers College, New York, 1923. Also in Curtis, ''Investigations in the Teaching of Science,'' Philadelphia, The Blakiston Company, 1926, p. 259.

conservation; evolution of man and animals and their struggle for existence; and the evolution of plants. A very small portion of the articles were devoted to topics considered fictitious.

The author of this study found that newspapers appeared to be more up-to-date on biological subjects than are college and high school texts. It is not intended that surveys of newspapers should form the sole basis for a course of study in biology, but it is conceded that they constitute an important contribution as a basis for formulating the biology curriculum. Teachers may find the articles beneficial and helpful as a rich source of material for biology classes.

THE CURRICULUM IN CHEMISTRY

Chemistry. The content of courses in high school chemistry is rapidly becoming more functional. The newer textbooks are organized on the unit plan or on a plan which can readily be organized so that the unit method of teaching can be utilized. The psychological method of approach is being employed in practically all newer textbooks. Instead of being organized on the logical basis, beginning with the more difficult fundamentals of chemistry, the approach to the subject is through the environment, as air, water, fire, and the like. The more difficult phases of chemistry, such as atomic weights and valance, are interspersed so that the pupil has more time to assimilate them. Under the logical type of organization, a large percentage of the pupils in a class were failures before the first two or three weeks were completed. The new type of organization tends to stimulate the interest of pupils in the chemical environment, gathering enough momentum to carry them through the more technical units.

Studies in the Chemistry Curriculum. One of the more important and recent studies in the chemistry curriculum is that made by Clarence M. Pruitt.[2] Varied types of printed materials were studied. He analyzed (1) the New South Wales, the New York State Regents, and the College Entrance Board examinations; (2)

[2] Pruitt, C. M.: "An Analysis, Evaluation, and Synthesis of Subject-matter Concepts and Generalizations in Chemistry," Ph.D. Dissertation, Teachers College, Columbia University, Published by author, New York, 1935. Also in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 153.

five books on sociology, comprising approximately fifty thousand pages of material; (3) one year's issue of each of three magazines—*The Atlantic Monthly, The Forum,* and *Harper's Magazine;* (4) one year's issue of eight newspapers; (5) 12 issues each of *Popular Science Monthly, Scientific American,* and *Science News Letter;* and nine issues of *Scientific Monthly.* In addition to this, he analyzed books in astronomy, biology, geology, physics, science, college textbooks of science, and nine years' issues of the *Journal of Chemical Education;* two textbooks of chemistry for high schools; and 22 popular books of chemistry.

Some of the more important findings of this study were: (1) Little chemistry was found in books on sociology, magazines of the type studied, and in the average type of newspaper. (2) A considerable amount of material in scientific magazines of general nature relates to structure, behavior, and properties of matter. Gas laws or the quantitative aspects of chemistry are given very little attention. (3) The chemistry contained in popular books on astronomy emphasizes the structure of matter and the use of the spectrum analysis technique in identification of elements. In physics books, more chemistry is found than in almost any other field, and structural matter is discussed widely. (4) Popular books in biology emphasize physiological and organic chemistry. (5) Popular books in science and chemistry contain a great deal of the more practical than of the technical phases of chemistry. (6) The questions of the New York Regents examinations and the College Entrance Board examinations give considerable emphasis to the technical phase of chemistry. (7) Emphases in college science textbooks are strikingly similar to those of high school.

As the result of the analysis of these materials, Dr. Pruitt formulated a list of generalizations in chemistry which merit inclusion in their entirety.[3]

> Matter is composed of the atoms and molecules of elements and compounds, ions, electrons, and protons.
>
> Substances have specific physical and chemical properties by which they may be identified.
>
> Every pure sample of any compound or element under similar conditions exhibits the same physical properties and chemical behavior.

[3] *Ibid.*, p. 157.

Chemical reactions may be initiated or affected, or both, by: heat, light, pressure, catalysts, concentration, the electric current, surface exposed, bacteria, hydrogen-ion concentration, and mechanical disturbances.

Elements and compounds produce physiological effects to which the cells of living organisms react specifically.

All matter may change its physical state by absorbing or releasing energy.

The relative velocity of molecules and their tendency to cohere determine the physical state of a substance.

Metals comprise a group of elements (other than hydrogen) whose atoms have a tendency to lose electrons readily and whose compounds when dissolved in polar solvents are capable of forming positive ions.

Atoms of the same element have similar properties but have different properties from the atoms of other elements.

Molecules of the same element or same compound are alike but are different from the molecules of other elements and compounds.

A given compound, whatever its origin, always contains the same elements in the same proportion by weight.

Enzymes, vitamins, and hormones are chemical regulators of the reactions that occur in living organisms.

The properties of alloys are dependent upon the relative amounts of their constituents and upon the crystalline structure of the particles.

Acids and bases are substances which in water solution ionize to give hydrogen or hydroxyl ions, respectively, from their constituent elements.

The solubility of solutes is affected by heat, pressure, and the nature of the solute and the solvent.

The ingredients of a solution are homogeneously distributed through each other.

The exchange of the negative and positive ions of acids and bases results in the formation of water and a salt.

When elements combine with each other, a substance is formed having properties almost entirely different from those their constituents had as elementary substances.

In a mixture, there is an intermingling of two or more substances with no fixed percentage composition and each ingredient retains its essential original properties.

The atoms of a given element are unvarying in average mass but are different in average mass from the atoms of all other elements.

Carbon atoms have the unique property of being able to form chain-molecules and ring-molecules.

Oxidation and reduction occur simultaneously and are quantitatively equal.

Oxidation involves the removal of electrons which increases the active valence of a positive element or decreases the active valence of a negative element, whereas reduction is the converse.

Every molecule of a given substance always contains the same number of the same kinds of atoms.

Carbon atoms form a number of "type-groups" of compounds which are determined by the elements present and by the structural combinations of the atoms within the molecule.

Electrolytes (acids, bases, and salts) when dissolved in a polar solvent or heated to a molten state, undergo dissociation into an equal number of oppositely electrically charged particles (called ions) capable of conducting an electric current.

An invariable relationship exists between the weights of atoms of all of the elements, and between these weights and the weights of all the molecules which these atoms form.

Matter is not created or destroyed in ordinary chemical changes.

Energy may be transformed in ordinary chemical and physical changes, but it cannot be created or destroyed.

Forms of energy are interchangeable.

A quantitative relationship exists between the weights of the substances that take part in a chemical change and between the weights of the substances reacting and the weights of the product.

Each element, with the exception of those that are inert, has a definite combining weight.

The physical and chemical properties of elements are periodic functions of their atomic numbers.

Ordinary chemical reactions involve either a transfer or a sharing of the outer electrons of atoms.

The differences between atoms of different elements are due to the number of electrons and protons in the nucleus and to the varying number of excess electrons in the shells surrounding the nucleus.

Crystalline structure, heat treatment, and impurities affect the properties of metals.

Pressure affects the boiling point, melting point, and freezing point of substances.

Atoms of radioactive elements are spontaneously emitting various rays and disintegrating into atoms of other elements.

Chemical reactions are brought about by combination, decomposition, displacement, exchange, and molecular rearrangement.

Chemical reactions go to completion when one of the products is a gas, or is insoluble or non-ionizable.

Chemical changes always involve an accompanying energy change.

The tendency of atoms to complete their outer shell by adding, losing, or sharing electrons determines their chemical activity.

Atoms become ions and ions become atoms, when either gains or loses electrons.

All gases and most liquids and solids expand with an increase in temperature and contract with a decrease in temperature.

Gram-molecular weights of non-ionizable substances or half gram-molecular weights of ionizable substances elevate the boiling point and depress the freezing points of solvents equally.

Non-metals comprise a group of elements whose atoms tend to gain electrons readily and whose compounds, when dissolved in polar solvents, are capable of forming negative ions.

Molecules containing carbon atoms have the property of combining with atoms of other elements either directly or by substitution.

Compression heats gases, resulting in increased molecular motion and pressure.

Each element in a state of incandescence has its own characteristic spectrum.

Molecules are in continual motion which molecular motion results in heat and pressure.

Every atom contains an equal number of electrons and protons which have a planetary system of arrangement within the atom.

Electrons and protons are arranged in some 92 patterns, most of which seem to be more or less distributed throughout space.

Metals may be arranged in an activity series according to their tendency to pass into ionic form by losing electrons.

Non-metals may be arranged in an activity series according to their tendency to pass into ionic form by gaining electrons.

Elements arranged in order of their increasing atomic numbers form themselves into a table of natural periods and groups in which the elements of any group have a close resemblance to each other in their respective chemical behavior and physical properties.

Heat increases molecular motion.

Each atom has the property of losing, gaining, or sharing a definite number of outer-shell electrons.

Each shell of an atom contains a definite number of electrons.

Mass of the atom is concentrated in the nucleus.

Atoms with complete outer shells are chemically inert.

Electrons revolve in circular or elliptical orbits about the nucleus.

The volume of any gas varies inversely as the pressure, if the temperature remains constant.

When chemical changes occur between gases, there exists a simple whole number ratio between the volumes of the reacting gases and the volumes of the gaseous product.

The activity of an acid or a base is proportional to the degree of ionization of the compound when in solution or in the molten state.

Equal volumes of all gases under similar conditions of temperature and pressure contain the same number of molecules.

A gram-molecular weight of all gases under similar conditions of temperature and pressure always occupies 22.4 liters.

Suspended particles of colloids have a continuous, erratic movement due to colloidal and molecular impacts.

Compounds may have the same number and kind of atoms but have different properties because of different atomic arrangement and space relations.

During electrolysis, the electrolyte is permanently decomposed, the cations moving to the cathode where they gain electrons and become atoms, and the anions moving to the anode where they lose electrons and become atoms.

Positive and negative ions unite to form molecules.

Each specific ion has a specific test by which it may be identified.

A gram-molecular volume of any gas contains approximately 6.062×10^{23} molecules.

Chemical changes between electrolytes in solution take place more readily than do chemical changes between non-electrolytes in solution.

The weight of gas which a given volume of inert solvent will dissolve is directly proportional to the pressure.

When an element combines with another element in more than one proportion, the different weights of that element which combine with a fixed weight of the second element, are always in the ratio of small whole numbers.

The relative rates of diffusion of gases under similar conditions are inversely proportional to the square roots of the densities of the gases.

The amount of heat evolved or absorbed in the formation of a given substance is always the same, regardless of the rate at which the reaction proceeds or the number of steps in which it takes place.

In a given chemical reaction, the speed of the reaction is proportional to the molecular concentration of each of the interacting substances.

All atoms (except those of hydrogen and helium) are built up from helium nuclei.

Heat, bases, acids, and oppositely charged particles cause colloids to precipitate.

In a gas the molecules have free and independent motion, are relatively far apart, and by virtue of their great velocity produce equal pressure in all directions.

In a liquid the motion of the molecules is less rapid than in gases and cohesive forces tend to hold the molecules closer together.

In a solid the motion of the molecules, ions or atoms is such as to cause them to have a somewhat vibratory motion about mean positions, a condition which may permit of crystalline structure.

The pressure exerted by each component in a gaseous mixture is proportional to its concentration in the mixture and the total pressure of the gas is equal to the sum of those of its components.

Colloids do not diffuse through membranes which are permeable to molecular or ionic dispersions.

A stream of moving electrons constitutes a current of electricity.

Two unlike metals in an electrolyte so react as to cause a flow of electrons.

Equilibrium exists in a chemical reaction when the rates of two opposing reactions of a reversible reaction are equal.

In reversible reactions, the products of the reaction react with each other to form the original reacting substances.

Colloidal particles carry electrical charges.

Radioactive changes involve nuclear changes.

Molecules of some compounds undergo polymerization.

During electrolysis, the amount of substances removed by deposition on the electrodes or released as a gas depends on the total quantity of electricity used.

Atoms behave both as particles and as waves.

Atoms with incomplete inner shells give colored ions.

The more electropositive or the more electronegative an element is, the greater the ease with which it loses or gains electrons.

Colloids have the property of adsorption to an unusual degree.

Electrons change orbits emitting or absorbing energy.

Orderly arrangement of atoms and ions in crystals gives crystals regular form.

Molecular motion ceases at absolute zero.

Heavier atoms may be broken down by bombarding the nucleus with alpha particles.

Atoms have great subatomic energy.

Electrons have a magnetic field.

Liquids usually have greater specific heats than solids.

Some elements have more than one atomic weight due to difference in the proton content of the nucleus.

If some stress is brought to bear upon a system in equilibrium, a change occurs so that the equilibrium is displaced in a direction which tends to undo the effect of the stress.

Each element has its own characteristic x-ray spectrum.

Elements may be changed into other elements.

Matter and energy are interchangeable.

Heat of formation and heat of decomposition are equivalent.

The boiling points of hydrocarbons increase with an increase in molecular weights.

Surface reactions predominate in colloidal reactions.

When the temperature of reacting substances in equilibrium is raised, the equilibrium point of the reaction is changed so that those products which absorb heat are increased in quantity, or if the temperature of the reacting substances is lowered, the products which evolve heat in their reaction are increased in amounts.

Salts of strong acids and strong bases undergo slight hydrolysis while salts of weak acids and weak bases undergo a more marked hydrolysis.

Molecular structure affects the properties of molecules.

Metals with loosely held electrons are good conductors of electricity and heat.

The nature and relative amount of the solvent, the presence of other ions, temperature, and light affect the degree of ionization.

For the same quantity of current, the weight of metal deposited or of the gas released is equal to the atomic weight divided by the valence.

For each gas, there is a critical temperature and a critical pressure.

Atomic volume is a periodic function of the atomic weight.

In a saturated solution, the product of the molar concentrations of the ions is constant.

Whenever the product of the concentrations of any two ions in a mixture exceeds the value of the ion-product in a saturated solution of the compound formed by their union, this compound will be precipitated.

Whenever the product of the concentrations of any two ions in a mixture is less than the value of the ion-product in a saturated solution of the compound formed by their union, this compound, if present in the solid form, will be dissolved.

Equal amounts of heat raise equal numbers of atoms of all elements in the solid state through equal intervals of temperature.

The specific heats of elements are inversely proportional to the magnitudes of the atomic weights.

If three elements combine together in pairs, then the quantities of two elements that combine with a fixed quantity of the other element bear a simple relation to the quantities of the first two elements that combine with each other.

When a chemical change takes place without the addition of heat from an external source, that substance which has the greatest heat of formation will tend to form.

Substances soluble in two or more immiscible liquids distribute themselves among the liquids in proportion to their solubilities.

Metals tend to lose electrons readily whereas non-metals tend to add electrons.

Alcohols have the properties of weak acids.

Alcohols oxidize to aldehydes, ketones, and acids.

Alcohols react with acids to form esters and ethers.

Saturated hydrocarbons are relatively inactive chemically, but form compounds by substitution.

Unsaturated hydrocarbons are very active chemically and form many compounds by addition and substitution.

This random list of generalizations is not functional for effective teaching in the order stated, but can be organized under major unit themes according to the judgment of the curriculum maker. A course in chemistry which includes these items should constitute a comprehensive course in chemistry for the secondary school.

Robert P. Wray[4] attempted to determine the relative importance of items of chemical information for general education. He analyzed four textbooks of high school chemistry, and secured

[4] *J. Exper. Education,* I, June, 1933. Also in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 164.

1,550 items of chemical information which he submitted to high school pupils, teachers, engineers, laborers, housekeepers, medical men, secretaries, business men, pharmacists, and nurses, all of whom had studied a minimum of one year of high school chemistry. These persons were requested to group these items according to usefulness. Dr. Wray concluded that the items of chemical information have consistently a relatively high utility for all individuals regardless of occupation, sex, or habitat. It was further observed that the beginning chemistry course can be adapted in a practical way to the needs of all pupils by building a chemistry curriculum around certain topics. The information which ranks high in usefulness may be taught to all. Advanced assignments on any unit of work may have quantitative and qualitative differentiation in accord with the abilities and future interests of the pupils.

Differentiated Needs of Boys and Girls. In many of the larger school systems, chemistry is differentiated on the basis of the needs of boys and girls; that is, offering a course in which only girls are enrolled and another in which only boys are enrolled. A very significant and skillful study was made in this area by Margery S. Gillson.[5] Dr. Gillson submitted a list of 100 carefully selected objectives in chemistry to about 950 people in various sections of the country. A second list of 94 objectives perfected from the preceding list with some additions was submitted to a special group of the author's 256 pupils who had finished high school three or more years before. Of these, 95 were boys and 87 were girls who had studied the usual college entrance course in chemistry, and an additional group of 74 girls who had entered a household chemistry class during a second semester of a one-year course. In the former group, these objectives were to be rated according to value as submitted by the valuator. The former pupils were requested to indicate the items which they had used rather frequently and those they had used occasionally.

Dr. Gillson presented two types of conclusions: those based on the data and those based on deliberation. She showed that: (1) More subject matter of chemistry is useful to both sexes than to

[5] Contributions to Education, No. 709, New York, Teachers College, Columbia University, 1937. Also in Curtis, "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 168.

either sex alone. (2) Chemistry as taught in high school does not function in the daily living of the pupils, probably because there is not enough correlation between the subject matter and actual living and because the quantity of factual information required of the pupils is greater than they are able to assimilate functionally. (3) Both men and women are interested in chemistry but, contrary to popular opinion, a larger proportion of women expressed a need for training in chemistry in adult life. (4) Adults recognize the value in the scientific method in solving problems. (5) Those responding consider the fundamental principles of chemistry to be of greater importance than factual information. The principles or generalizations which were found to be most functional for laymen are: composition of matter; the nature of chemical action and chemical equations; the properties of acids, bases, salts, and carbon compounds; and the chemistry of metals. The principle of oxidation and reduction and the periodic classification of elements rated low. (6) Unpopularity of the secondary school chemistry course is due to the inclusion of too much mathematics, frequent meaningless laboratory work and its reputation of being difficult.

The conclusions based on deliberation[6] are as follows:

1. "The chemical principles and generalizations which are essential to the understanding of the science, and which will occur frequently in the beginning course and also in many situations in later life seem to be the following: chemical changes—meaning of the term and knowledge of the various types, also some ability in expressing these changes as the chemist does; the oxidation-reduction principle; the theories concerning the structure of matter—atomic, molecular, electronic; conservation of matter and energy; the constant composition of substances and their consequent definite properties; the conditions affecting, and the properties of, solutions, including the ionic theory and some study of electrolysis and colloids; the principle of neutralization and the attending knowledge of the properties of acids and bases; the nature of the metals and non-metals; the electro-chemical series; the periodic law; elements of radio activity; the classes of organic compounds; the chemistry of the human body—food needs, food changes in the body, effects of a few drugs; and enough knowledge concerning textiles and dyes to make intelligent consumers. Chemical principles and generalizations which may be omitted are the laws of Boyle and Charles, the law of multiple proportions, the law of combining volumes of gases, and Avogadro's Hypothesis."

[6] Curtis, *Ibid.*, p. 171.

2. ". . . The chief change in the subject matter of the usual high school chemistry course should occur in the second semester as now organized. The detailed study of metals should be omitted for girls and a rather extensive study of foods and textiles put in its place. Their study of metals should concern the care of those encountered in the home. This would include the action of the metals with the various acids in food or cleansers and with the air." The study of the principles and generalizations (listed in the second preceding paragraph) "should continually be related to the daily lives of boys and girls in order to arouse their interest and help them to see that chemistry does have functional value for them. Let them analyze or study materials brought from home. The mathematical phases of the subject would not be stressed in a course planned to give girls the chemistry that will be of use during all their lives."

3. ". . . boys would like to know more concerning the structure of matter, the theory of solutions, and the mathematics of chemistry than would girls."

4. "For both boys and girls . . . the starting point of the course should be practical, not theoretical." In order to overcome fear of the course and to develop appreciation of it, "some time should be spent early in the course in giving the class an overview of the achievements of chemistry in industry, agriculture, and medicine.

5. Laboratory work should form an integral part of the course, closely tied to the classroom discussion and study, and should afford a means of acquiring knowledge first-hand rather than of verifying facts and principles already known.

6. "The slavish use of a single textbook" should be abandoned in favor of gathering data from many sources.

7. Teachers of chemistry must be broadly trained in order that they may orient the pupils and provide a functional course.

8. ". . . if our beginning students are to receive material which will be vital to them, the traditional course must be altered. . . ."

THE CURRICULUM IN PHYSICS

Physics has been one of the least popular science courses in secondary schools and has tended to be on the decline in enrollment in the larger school systems where it is an elective subject. This lack of interest in physics is primarily due to its traditional organization and method of teaching. A high school course in physics is too much a college course with reduced content. It is, therefore, too technical and theoretical, containing too much mathematical calculation to permit of an adequate mastery by the average high school pupil. Progressive physics teachers who have attempted to make the course in physics more practical have reversed this trend,

finding that the facilities and the number of classes offering physics have to be increased rather than reduced. Physics should be one of the most popular and practical subjects offered in secondary schools for both boys and girls because of the increasing physical features of the environment in which these young people have to live today.

STUDIES IN THE PHYSICS CURRICULUM. There are a few studies which are worthy of summary. Watson,[7] in a critical study of the content of high school physics with respect to its social value, prepared a questionnaire which contained a list of 174 topics including practically every device, other than strictly laboratory devices, which was described or illustrated in any one of three well-known texts in physics. Each pupil studying physics in 75 high schools in Kansas was asked to have his parents fill out the questionnaire and to check the topics according to whether or not they were worth while, of doubtful value, or of practically no value. According to the evidence there are numerous topics discussed in physics texts which are of little practical value for the majority of adults. On the other hand, numerous physics topics of recognized value are not included. An individual's occupation is a less significant factor than commonly supposed in the choice of content for high school physics courses. The correlation between the choice of worth-while topics in a high school course is more than .90 among farmers, mechanics, professional men, merchants, and women. The topics of greatest importance to 659 adults in order of frequency of mention are as follows: thermometer, ice cream freezer, ordinary kitchen range, ordinary heating stove, door lock, sewing machine, fountain pen, window shade roller, oil stove, how to regulate a clock, kerosene lamp, fever thermometer, firing gun (ordinary rifle), cream separator, spectacles, water faucet, crowbar, block and tackle, automobile tires, and automobile jack.

Downing,[8] in an attempt to determine the most important principles of physics and their relative importance, synthesized the

[7] *School Review, 34*: 688–697, 1926. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 209.

[8] Downing, E. R.: Techniques for the determination of basic principles in science courses, *Science Education, 14*: 298–303, 1929. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 211.

data from four studies, two of which determined the principles of physics appearing in farm journals; one determining the principles found in trade journals; and one, a job analysis of the activities of the housewife to find what principles of science she needs and to what problematic situations these apply. Thirty-two principles of physics were found which appeared in two or more of these lists. These principles are as follows:[9]

A body is stable when its center of gravity is over its base.

Equilibrium: When the resultant of all the forces acting upon a body is zero no change of motion of the body is produced.

Parallel forces: The resultant of forces acting in opposite directions along the same line is a force equal to their difference, acting along the same line in the direction of the greater.

Atmospheric pressure: The gases of the atmosphere (the air) have weight and exert a pressure of 14.7 lbs. per square inch at sea level. This pressure is transmitted in all directions and is proportional to the height of the column of air.

Boyle's law: The temperature remaining the same, the volume of a given body of gas varies inversely as the pressure upon it.

Pascal's law: The pressure applied to any part of an enclosed fluid is transmitted undiminished throughout the fluid, with unchanged intensity, to all parts of the interior surface of the vessel, and its direction is everywhere perpendicular to the surface.

Gravity pressure: The pressure at any point in a liquid at rest is directly proportional to the density of the liquid and to the depth of the point below the free surface of the liquid, and at any point the pressure is the same in all directions.

Archimedes' principle: A body either wholly or partially immersed in a liquid is buoyed up by a force equal to the weight of the liquid displaced by it.

Lever: The moment of the effort applied to a rigid bar capable of moving about a fixed point is equal to the moment of the resistance.

The pulley: The force applied to a pulley system times the distance through which it moves is equal to the product of the resistance times the distance through which it moves, and the ratio of the force applied to the resistance is proportional to the number of ropes pulling on the movable pulley.

The inclined plane: By means of an inclined plane a weight can be lifted by a force that has the same ratio to it as the length of the plane has to the height of the plane.

Friction: When two moving bodies come in contact they produce a resisting force which, in sliding motion, is proportional to the pressure and independent of the extent of the surfaces in contact. Rolling friction depends upon the hardness and smoothness of the surfaces in contact.

[9] *Ibid.*, Curtis, p. 212.

Hooke's law: Whenever the forces that produce distortion in a body are within the elastic limit, the distortion produced is directly proportional to the force that produces it.

Capillarity: If a solid be immersed in a liquid which wets it, the liquid will rise about the sides of the solid; if the liquid does not wet the solid, it is depressed about the solid.

Osmosis: A kind of unequal diffusion takes place between two miscible fluids separated by porous septa. Rate varies with concentration.

Inertia: Every body continues in its state of rest or uniform motion in a straight line, except in so far as it is compelled to change that state by a force impressed upon it.

Work is the accomplishment of results, being the product of the mass and the distance moved.

Magnetism: Like magnetic poles repel and unlike poles attract each other. The force of attraction or repulsion varies directly as the magnetic strength of the poles and inversely as the square of the distance between them.

Ohm's law: The electric current varies directly as the electromotive force and inversely as the resistance.

Electrical heating: The heat developed by a current in a circuit is proportional to the square of the current, to the resistance of the circuit, and to the time during which the current passes.

Induced current: A current of electricity may be induced in a conductor by causing the latter to move through a magnetic field.

Transference of heat: Heat may be transferred by convection currents, conduction, and radiation.

Change of state: Metals may be liquefied and liquids vaporized by the application of heat, and vice versa.

Gases and most liquids and solids expand on heating and contract on cooling.

The heat required to change a substance from one form to another is equal to the heat given off when the process is reversed.

Bodies expand on heating in proportion to the rise in temperature.

Light manifests itself in the form of ether wave vibrations which travel in straight lines.

Reflection: The angle of incidence equals the angle of reflection.

Refraction: When a light ray passes at an oblique angle from one medium to a more dense medium, it is bent toward the perpendicular; conversely when a light ray passes obliquely from a medium to a less dense medium, it is bent away from the perpendicular.

Illumination: Intensity of illumination varies inversely as the square of the distance from the source of illumination.

Frequency of vibration of a string varies inversely as its length, radius, and square root of its density, and directly as the square root of its stretching force.

Heat is conducted in different degrees by various substances. Rate depends on difference in temperature of source and conductor.

Two comprehensive studies were made on the content of laboratory experiments in physics under the direction of Francis D. Curtis by Hazen S. Slack[10] and by E. W. Kiebler.[11] One study[10] attempted to determine what exercises in physics laboratory were most frequently required in nine of the Detroit high schools. It was found that considerable variance existed in the lists for the individual schools. However, there were 14 laboratory exercises which appeared in each of the basic lists and are as follows:

Mechanics:
- Measurements—with meter stick.
- Measurements—with vernier calipers.
- Density and specific gravity of solids by measurements.
- Buoyancy: symmetrical solids heavier and lighter than water (volume determined by measurements and displacement).

Buoyancy: irregular solids.
- Concurrent forces.
- Parallel forces.
- Pendulum—laws.
- Inclined plane.

Sound:
- Lengths and tensions of vibrating strings.

Light:
- Convex lenses—focal lengths and images.
- Index of refraction of glass.

Heat:
- Specific heat of various metals and solids.
- Heat of fusion.
- Heat of vaporization.
- Coefficient of linear expansion of metals.

Magnetism:
- Magnetic field and poles (blue print).
- Laws of magnetic attraction and repulsion.

[10] *School Science and Math.*, *27*: 163–167, 1927. Also in Curtis, F. D.: "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 216.

[11] *School Science and Math.*, *29*: 980–985, 1929. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 219.

A list of laboratory exercises in physics required in from five to eight of the nine Detroit high schools makes a more adequate source and is as follows:

Mechanics:
1. Measurements—with micrometer calipers.
2. Boyle's law.
3. Buoyancy—determination of density of liquids.
4. Acceleration on inclined plane.
5. Hooke's law (with spring).
6. Pendulum—determination of g.
7. Pulleys.
8. Center of gravity of meter stick by principle of moments.
9. Wheel and axle.

Sound:
1. Velocity, by resonance in tubes.
2. Siren.

Light:
1. Photometry.
2. Plane mirror—laws of reflection and images.
3. Concave mirror—focal length and images.
4. Index of refraction of water.

Heat:
1. Thermometer—fixed points.
2. Thermometer—calibration (graph).
3. Cooling through change of state.
4. Determination of water equivalent.
5. Mechanical equivalent of the calorie.

Electricity:
1. Electromagnet—testing polarity.
2. Wheatstone bridge.
3. Resistance—voltmeter-ammeter method.
4. Electromagnet—its construction.
5. Electromagnet—effect of introducing core in helix.
6. Primary cells—electromotive series.
7. Induction—magnets and coils.
8. Resistance—substitution method.
9. Connecting up electric bell and telegraph.
10. Primary cells—kinds of electrolytes.
11. Electroplating.
12. Heat equivalent of electric current, 1 joule = .24 calorie.

The second study[11] involves a listing of the laboratory exercises found in eight laboratory manuals for high school physics. The complete list of exercises is grouped into five familiar classi-

fications: Mechanics, heat, light, sound, and electricity and magnetism were sent to several hundred experts for evaluation. These evaluators were requested to rank each exercise one, two, or three respectively, to indicate whether the exercise is essential in a one-year high school course of physics, merely desirable if time permits, or undesirable in such a course. The result indicated that there is considerable lack of agreement both between authors of laboratory manuals and among teachers of physics regarding what exercises should be incorporated with a laboratory course in high school physics. None of the 175 exercises included in a total list, was considered essential to a course by all these evaluators, and only four appeared in all of the laboratory manuals.

The laboratory exercises in physics which appeared in more than half of the laboratory manuals and which were considered essential by more than half of the evaluators are as follows:

Mechanics:
- Specific gravity of heavy solids.
- The lever.
- Inclined plane.
- Archimedes' principle.
- Specific gravity of light solids.
- Hooke's law.
- Resultant of two forces at an angle.
- Boyle's law.
- Pendulum.
- Parallel forces.

Sound:
- Laws of vibrating strings.
- Velocity of sound.

Light:
- Image in plane mirror.
- Refraction (glass).

Heat:
- Specific heat.
- Latent heat of fusion.
- Humidity.
- Zero point of thermometer.
- Heat of vaporization.
- Boiling point on thermometer.
- Coefficient of expansion of solids.

Electricity and magnetism:
- Lines of force about a magnet.

Voltaic cell.
Magnetic effect of a current.
Dynamos and motors.

Laboratory exercises in physics appearing in more than half the manuals but considered essential by fewer than half of the evaluators are as follows:

Mechanics:
- Pulley.
- Weight of lever (principle of moments).
- Specific gravity by hydrometer.
- Laws of friction.
- Area of a triangle.

Sound:
- Frequency of vibration of tuning fork.

Light:
- Photometer.
- Refraction (water).
- Telescope and microscope.
- Concave mirror.

Electricity:
- Resistance by Wheatstone bridge.
- The electroscope.

Laboratory exercises in physics appearing in fewer than half the manuals but considered essential by more than half the evaluators are as follows:

Mechanics:
- Efficiency of machines.
- Barometer.
- Comparison of English and metric units.
- Volume of irregular body.

Sound:
- Length of sound wave.
- Resonance.

Light:
- Images formed by lens.
- Laws of reflection.
- Dispersion of light by prism.
- Focal length of a lens.

Electricity:
- Induced current.
- Electrolysis.
- Grouping of cells.

Resistance by voltmeter-ammeter.
Electrotyping.
E. M. F.
Ohm's law.
Storage battery.
Electric bell.

The preceding lists of laboratory exercises in physics can be helpful in guiding the secondary school physics teacher in formulating a functional series of physics laboratory learning activities. Adaptations to local needs can readily be effected by means of omissions and additions according to the judgment of the teacher.

STUDY QUESTIONS

1. What are the needs in the content of senior high school science?
2. Compare the present status of the content in biology with that of chemistry and physics.
3. Give some of the evidence that chemistry is found in current popular readings.
4. What are some of the generalizations in chemistry which should be included in a course in chemistry?
5. Do boys and girls have different needs relative to senior high school science?
6. What are some of the traditionally taught principles in secondary school science which may be omittted?
7. How may physics be made more popular as a secondary school subject?
8. What are some of the more important principles which should be included in physics?
9. What is the status of the content of laboratory work in secondary school physics with respect to uniformity?

ADDITIONAL PROBLEMS AND PROJECTS

1. Make a report to the class or write a comprehensive summary of one of the more important studies in the senior high school curriculum.
2. Prepare a list of the units which should be included in a senior high school science subject of your choice, and prepare a list of problems which should be included in a unit in any science subject of your choice in senior high school.

SELECTED REFERENCES

See references at the end of Chapter 5.

UNIT THREE

The Function of Method in Science Teaching

In the three chapters included in this unit an attempt is made to present one method of science teaching in detail, namely the unit plan. Other techniques, parts of which may be incorporated with the unit plan, are discussed more briefly. Specific suggestions are given which will aid the beginning teacher in implementing the functional parts of all techniques.

The unit plan of teaching science in the secondary school is not definitely defined as to form. Very few teachers adhere strictly to the Morrison Unit and the Herbartian five steps. Such modification is desirable so that each teacher's technique may be best adapted to his personality and background.

Methods characterized by the lecture, question and answer, reference work, contracts, project and flexible assignment may be incorporated wholly or in part into the unit plan as herein described.

Two phases attend the careful planning of a unit of instruction in science: (1) organization of the unit, and (2) administration of the unit. In organization the content is limited to a certain theme which is comprehensive, unifying and significant; the aims and types of objectives to be achieved are determined; and the types of activities are suggested. The administration of the unit involves a detailed procedure in how to give the pupil learning experience which will aid him in reaching the outcomes or objectives set forth in the organization of the unit.

7

The Learning Unit as a Method of Teaching Science in the Secondary School

There is no royal road to learning, but there are techniques of imparting information and of effecting growth of pupils which are more efficient than other methods. It behooves those who are in the field of education to employ the methods which have been found to be most effective in the light of our scientific studies in teaching procedure and educational psychology.

IMPORTANCE OF EFFICIENCY

Efficiency is mandatory in every field of activity whether it be personal service, manufacturing, or selling goods, because improved methods are continuously being developed in these areas and people are constantly demanding that they receive the benefits derived from the development of more efficient methods. If the same techniques of instruction were used today which were employed during the early colonial days, the cost of education would be greatly increased.

Historical. It may be helpful to trace the development of improvement in the methods of teaching beginning with the earliest colonial systems of education. Efficiency in teaching is usually characterized by a maximum amount of growth in the minimum amount of time with a minimum amount of financial expenditure.

Apprentice System. The first method of teaching in the colonial period was the apprentice system. Under this system the apprentice received training in reading, writing and possibly was taught a vocation or trade in exchange for services as a hired man. Under this system the remuneration amounted to the bare necessities of life—room and board and possibly some clothing. Apparently the apprentice system was approximately one hundred per cent efficient in the matter of caring for individual differences because

there was one teacher and one pupil. As the demand for literacy increased, it was evident that on the basis of one pupil for each teacher there were not enough teachers to go around.

Dame Schools. The next development was the Dame school in which a mother, while teaching her own children, would also accept the responsibility of teaching her neighbors' children for a small remuneration. Under this plan, the mother would teach these children how to read and write while they sat around her in a group, possibly in her kitchen. This made for somewhat greater efficiency in teaching since such a teacher could teach the same subject to from five to 15 or 20 children at one time. Obviously, the care of individual differences was greatly reduced.

Lancastrian Schools. As the demand for free public education increased, other forms began to develop through the expansion of taxation for school support. The money that was available for taxation was very meagre; therefore, an attempt was made to teach a large number of pupils with one teacher. The extreme case of this type was the Lancastrian type of school wherein one teacher, with the assistance of monitors, would teach from 200 to 1,000 pupils. In this Lancastrian type of school the force of economy had its greatest effect.

Graded School. Shortly after Horace Mann visited the schools of Germany where the graded system was in practice, this pattern was instituted in the United States. It scored a success for the principle of ministering to the individual, because a teacher had smaller groups, ranging from 25 to 40 children, under his supervision. Economy, however, again scored a victory when women teachers were hired to replace men at from one-third to one-sixth of the salaries paid the men. In the early grade schools one principal was employed at $2,000 a year and five women teachers were employed at $400 a year. In other words, five or six women teachers could be hired for the same amount as one man teacher. This obviously helped to reduce the cost of more efficient education. Since the establishment of the graded school by Philbrick in 1848, scores of organization plans have been developed in an effort to effect a compromise between economy and the principle of ministering to the individual. A majority of the individualized plans of instruction were developed after World War I.

Individualized Plans. Among these plans were the five- to nine-week promotion periods which were introduced by Dr. Harris of St. Louis as early as 1870. Other plans which were evolved were the Pueblo Laboratory plan, the Winnetka, Batavia, Cambridge, Denver, Platoon, and Dalton plans. Later, with the development of mental testing, came the ability grouping, such as the XYZ groups in Detroit, which were among the earlier adaptations. Ability grouping serves to care more adequately for individual differences in large groups. There are many advantages and disadvantages, however, and much disagreement among educators as to the efficacy of this plan. Ability grouping still is extensively used, and rightly so.

It is seen from this discussion that there is a perpetual struggle between these two major forces—the forces of economy and the objective of ministering to the individual child. These two forces will continue to act upon the practices of teaching methods and school organization, bringing about continuous change, probably toward the improvement and greater efficiency in the teaching method.

THE UNIT PLAN

During the decade following World War I a comprehensive unit plan was developed by Professor Morrison from the University of Chicago, and described in his book, "The Practice of Teaching in Secondary Schools."[1] This plan and modifications of it have been the object of rather wide experimentation throughout the country. It purports to care for individual differences in large groups by means of study guides which permit individual progress according to the pupils' interests and abilities. It also provides for individual initiative and for enriched activities for the more capable pupils.

A Concept of the Unit. A learning unit in secondary school science may be conceived as a series of group-planned, related, and unifying experiences or activities in which secondary pupils participate in order to achieve an adaptation to, or control over, an area of living. The learning activities contribute to the understanding of significant and comprehensive principles which are func-

[1] Morrison, H. C.: "The Practice of Teaching in the Secondary School," Chicago, University of Chicago Press, 1926.

tional in contemporary and ultimate living. These principles may be unified and integrated into a learning product such as "How to Keep Physically Fit," "The Nature of the Earth's Crust," "The Earth is an Insignificant Part of the Universe," and the like. This learning product is an integrated combination of skills, attitudes, habits, knowledge, appreciations, and understandings which will effect an adjustment by the learner to a life situation.

Units may differ in scope depending upon the background and maturity of the pupils. This variance may be in breadth and depth or intensity, the breadth decreasing with an increase in grade level and the intensity increasing as the pupils progress toward the more specialized science subjects in the senior high school. For instance, pupils of junior high school age, in studying elementary science, may investigate "Living Things on the Earth" while tenth grade biology pupils determine "How Living Things Maintain Their Kind." Likewise, while junior high school pupils would investigate "Air is Necessary to Life," the chemistry class in the senior high school would study "Nitrogen and its Compounds."

The unit plan permits the application of all accepted principles of learning. It permits the application of *Gestalt* psychology in that an over-view of the unit may be presented by the teacher with the help of the pupils before the actual assimilation activities of the unit begin. This preparation and a pre-test which aids in effecting the apperception approach and motivation through getting the whole picture makes use of Thorndike's first law of learning which is "Readiness."

After this over-view has been presented, the assimilation period begins, during which the actual learning by the pupils takes place. This provides for pupil activity aided by study guides which direct the individualized work of each pupil in the class regardless of size. This carries out the second law of learning, which states that "exercise" or practice is necessary for an organism to grow in any certain skill, habit, or attitude. This practice is continued until these abilities are mastered, at least relatively so.

This relative mastery incorporates Thorndike's third law of learning which is "effect." It is generally true that satisfaction is not achieved by any learner until a relative mastery is achieved in any skill or area of learning. The facilities which care for indi-

vidual differences under this plan permit each pupil to achieve to his individual capacity or satisfaction. Keeping in mind that "Nothing Succeeds like Success," every teacher should endeavor to organize the learning experiences so that each pupil succeeds in the task which is attempted by him.

Evaluation of the Unit Plan as a Method of Teaching Science. Controlled studies have failed to prove objectively that the unit plan is superior to other specific plans such as the daily recitation, project, and the like as far as measurable learning products are concerned. Nevertheless, critical evaluation on the basis of modern philosophies of education gives the unit plan advantages over other methods of teaching. Some of these advantages are the following:

1. Caring for individual differences is possible to a greater degree.
2. Pupil activity instead of teacher activity may be emphasized.
3. It affords challenges to brighter pupils.
4. It permits more complete mastery according to individual capacity.
5. It procures individual pupil effort to a greater degree.
6. It permits the use of a wide variety of learning activities such as extensive reading, problems, individual experiments, projects, oral reports, written reports, and the like.
7. It facilitates remedial work.

Practically all disadvantages which are claimed to be disadvantages attendant to the use of the unit plan can be overcome by the alert teacher. Some of these disadvantages are (1) use of guide sheets tends to make learning monotonous, stereotyped and lacking in freshness; and (2) overburdening of teacher with written work. On the contrary, guide sheets may serve to enrich and make the activities more challenging for all the pupils and the utilization of certain techniques of checking the written work and the employment of group testing can eliminate both these disadvantages.

The manner in which these advantages may be realized and how disadvantages may be overcome are discussed in the succeeding chapters.

Corbally[2] made a study to determine the relative effectiveness of two plans of teaching general science; the assignment-recitation

[2] *School Review, 38*: 61–66, 1930. Also in Curtis, F. D., "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1931, p. 105.

plan and the unit plan. The subjects of this investigation were four classes in general science which were matched according to ability, and the theme of the unit was the gasoline engine. Each of the pair of groups was given a preliminary test and one was found to have an average of 12.19 errors, while the second had an average of 12.22 errors on this same test. The period of experimentation was three months. Classes 1 and 4 were taught by the unit procedure and classes 2 and 3 were taught by the assignment-recitation plan.

The findings were as follows: (1) The group taught by the Morrison plan made a slightly better record on the immediate test, but the difference between the two groups was so slight that no superiority of one method over the other in its effect on initial learning could be claimed. The average number of errors made by the group taught by the Morrison plan was 4.14, and the average for the assignment-recitation group was 4.24. (2) The group taught by the Morrison plan made a better showing on the memory test. These facts tend to show that the Morrison plan is more effective in fixing facts than is the assignment-recitation plan. (3) In this study the range in number of errors made by the group taught by the Morrison plan was greater in the case of the memory test than in the case of the immediate test. (4) The general conclusion of the study is that neither method is distinctly superior to the other, and that the determining factor is the teacher, not the method or device.

There is a definite lack of studies evaluating the unit plan as compared with other plans, though the philosophy supporting it suggests that it is superior. A few evaluators feel that the more extensive reading done by pupils under the unit plan justifies its use in spite of the fact that achievement, when measured by the present measuring devices, indicates no superiority. In other words, they believe that if the achievement by the unit plan is just as high, it is justifiable because of the broad growth which is made possible.

Shelton[3] made a study similar to that by Corbally and obtained similar results. He used four more extensive units on "Weather," "Water Supply," "Work," and "Engines." Tests were given on factual knowledge and ideas. The results of this study indicated

[3] Shelton, A. L.: Experimental study of daily recitation versus unit plan, *School Review, 38*: 6949, 1930.

that neither method was superior. The unit plan was slightly better for teaching factual knowledge, but the daily-recitation plan was superior in teaching ideas.

In attempting to determine the attitude of pupils toward the unit plan of teaching, Billet[4] concluded that boys and girls of all levels of academic intelligence, accomplishment, and application, whether the subject matter is geometry or English, regard the unit plan as a distinct improvement over the traditional recitation procedure.

ORGANIZATION OF A SCIENCE TEACHING UNIT

The first step in organizing a teaching unit is to decide what the unit theme should be. This theme should be comprehensive and unified, adequate in breadth but not too broad. The length of a satisfactory unit depends upon the age level at which the subject is being presented. The optimum unit for junior high school probably is two weeks, while for senior high school the length may be extended to three or even four weeks. The theme may be stated in the form of a sentence, such as "The Earth is an Insignificant Part of the Universe," "Machines are of Great Help to Man in Doing His Work," "The Human Body Needs to be Protected," and the like. Topical forms of stating the unit theme may not be as effective as a sentence which states a definite idea or concept.

Sometimes it is helpful to state next in order the major ideas or major concepts which are to be covered in the unit. These may be stated in three or four sentences, for example, "The earth on which we live is a small body among millions of other heavenly bodies, some of which have a great influence on this great earth of ours," or "The human body is like a machine and needs to be kept in condition and adequate repair. Human energy must be conserved in order that the human being may live as long as possible."

The next step in organizing the unit should be the formulation of the objectives which are described in the previous chapter, and the adaptation of these objectives to a unit on the three-level plan, namely, aims, general objectives, and specific objectives. The objectives which are ministered to in the unit should be the only ones

[4] Billet, R. O.: High school pupil opinion of the unit plan, *School Review*, *40*: 17–32, 1932.

included. In the case of the aims, only the aims which are ministered to by the learning experiences which the pupils have in this unit should be listed. For instance, for the unit on the heavens, only three cardinal principles may be directly ministered to: worthy use of leisure time, vocational efficiency, and ethical character. It is not enough merely to list these cardinal objectives, but a descriptive statement as to how these may be achieved should be added, such as: "Worthy Use of Leisure Time—the pupil may become interested enough in the stars to select the ones he identifies during the night walks and further to study the heavens." Likewise, for a vocational objective an addition may be made: "This interest may be carried out in later life to the extent of choosing astronomy as a life work."

Another illustration may be given of the objectives in another unit, namely, dependent organisms in relation to man. In this unit, the cardinal principles are ministered to but the learning experiences are somewhat more numerous than in the case of the unit on astronomy. This unit ministers to health, worthy home membership, citizenship, and vocation. An understanding of dependent organisms contributes greatly to the personal health of the individual. It will make an individual a better citizen in that he can more intelligently cooperate in community health. It makes a person a more worthy home member because a realization of the necessity of cleanliness in the home would be achieved. The child participating in the learning experiences provided in this unit would become interested in the dependent organism to a degree that would reveal this study as a possible life vocation as a bacteriologist, physician, or nurse.

In the category of general objectives may be placed the general knowledges, attitudes, skills, habits, and the like which are not directly developed by the experiences of the specific learning unit. For instance, the general objectives for a unit on the heavens may be as follows: (1) knowledge of subject matter leads to understanding of the universe; (2) discovery and development of correct study habits; (3) ability to interpret diagrams; (4) skill in use of test for reference work; (5) the development of wholesome interests in the subject of stars, planets, etc.; (6) the development of a scientific attitude toward the environment; (7) development of

appreciation of the vastness, complexity, and orderliness of the universe.

In a unit on health, the general objectives may be listed as follows: (1) to secure general knowledge regarding the basic health habits, including cleanliness, exercise, and foods; (2) to secure an appreciation of the necessity of good health as a prerequisite to the living of a full life, and a scientific attitude toward health problems such as the abolition of superstition and supernatural forces in the curing of disease; (3) recognition of reliable authorities in health matters; (4) to develop interest in maintaining a high state of personal and community health.

In the next classification, specific objectives, may be included the knowledges, skills, and attitudes which are measurable by our present methods of measurement. These objectives can be measured more directly and objectively than the categories mentioned above. For example, in a unit on the heavens they may be as follows: (1) to learn how the universe is organized; (2) to know the nature of the heavenly bodies; (3) to know how stars can be located; (4) to know how the earth is affected by heavenly bodies; (5) to know how position on the earth is located; (6) to know how standard time is determined.

Taking again a set of specific objectives for our unit in health, we may state them as follows: (1) to know what dependent organisms are helpful and harmful to man; (2) to know what precautions can be taken to prevent the contraction of communicable diseases; (3) to know what common cures are available for bacterial diseases; (4) to know the proper habits in eating and the kinds of foods to eat; (5) to know what special benefits are derived from certain common or necessary foods; (6) to know the disease possibilities in improper care of unstable foods such as milk; (7) to know the common functions of the human body: (8) to know the action and operation of some of the major organs of the body; (9) to know the fundamentals and common requirements of first-aid; (10) to know some of the major cautions in the care of the human body; (11) to know some of the more common emotional and psychological reactions of the human body.

The next step in the organization of a unit is the formulation of the major problems under the unit. In order to effect a connec-

tion between the objectives and the actual learning experiences in a classroom, it has been found beneficial to restate the specific objectives in the form of questions. This makes it possible to get a direct connection between the philosophy of education and the actual activities which the teacher provides for the pupils. In the case of our unit on the heavens they may be stated as follows: (1) How is the universe organized? (2) What is the nature of the heavenly bodies? (3) How can the stars be located? (4) How is the earth affected by the heavenly bodies? (5) How is position on the earth located? (6) How is standard time determined?

In addition, the plan of organization for the unit should include, (1) a general list of activities in which the pupils may participate; (2) the activities for which the teacher is to be responsible, and (3) a list of references and materials which are needed to provide the pupil with experiences related to the unit.

Pupil activities which should be listed may include items such as, (1) answering questions on the study sheet; (2) making drawings; (3) preparing demonstrations and reports; (4) participation in class discussion; (5) pursuing independent study outside of class, and the like.

Teacher activities may comprise such responsibilities as, (1) preparing and administering the study guide; (2) leading class discussion; (3) planning and performing experiments before the class; (4) supervising pupil activities during the class period; (5) encouraging pupil study outside the class period; (6) providing special references; and (7) testing results.

References and materials are a very important part of the planning of a unit and should largely be predetermined in relative detail. References which are not permanently assigned to the science room should be listed and procured from the school library for the duration of the unit. Other helpful references also should be listed for the convenience of the pupils.

Equipment and material should be listed so that a check can be made of that on hand; additional needed equipment and material can be procured from other departments or sources. All equipment and material should be on hand before they are needed, preferably before the unit begins.

A skeleton sample of the organization phase of a general science unit may be helpful.

SAMPLE LESSON PLAN

Unit Organization

I. Unit theme: The earth is an insignificant part of the universe.

II. Major concept: The earth on which we live is a small body among millions of other heavenly bodies some of which have a great influence on this earth of ours.

III. Objectives:

A. Central Objectives or Aims.

1. Worthy use of leisure time. (The pupil may become interested enough in the stars to select the ones he identifies on night walks, and to study further about the heavens.)
2. Vocational. (This interest may be carried out in later life to the extent of adopting astronomy as a life work.)
3. Ethical character. (Contemplation of the vastness, complexity, and perfect order of the universe cannot help but lead to a broader understanding on the part of the pupil of his own position in relation to the rest of creation.

B. General Objectives.

1. To develop and to discover correct study habits, abilities, skills, through correct analysis of text, use of diagrams, interpreting figures, symbols, careful reading and thinking.
2. To develop wholesome interests through a desire to find out more about the heavens.
3. To achieve knowledge of subject matter which leads to an understanding of the universe.
4. To develop scientific attitudes toward environment to help pupils realize the value of a study of the heavens.

C. Control or Specific Objectives.

1. To learn how the universe is organized.
2. To know the nature of the solar system.

IV. Major problems:

A. How is the universe organized?

B. What is the nature of the solar system?

V. Pupil activity:

A. Write answers to questions on guide sheet.

B. Make diagrammatic sketches of constellations, phases of the moon, etc.

C. Perform, demonstrate, and observe experiments.

D. Prepare special reports on phases of the unit, current astronomical news, etc.

E. Participate in class discussion.

F. Do independent study outside of class.

G. Participate in evaluation.

VI. Teacher activity:

A. Provide and administer work on guide sheet.

B. Lead class discussion.

C. Plan and perform experiments.
D. Supervise pupil class activities.
E. Encourage study outside of class.
F. Provide special references.
G. Test results.

VII. References and materials:
A. Text.
B. Additional references.
C. Equipment and materials.

STUDY QUESTIONS

1. Why is efficiency the main objective in a method of teaching?
2. What are the characteristics of efficient teaching?
3. Trace the evolution of the organization of the American public school.
4. What type of teaching method appears to satisfy the present needs?
5. Give the advantages of the unit plan of organization and teaching of a school subject.
6. How does the unit plan of teaching compare with the traditional plans with respect to measurable results achieved?
7. What are the advantages of the unit plan over the traditional plans which are not objectively measurable?
8. Give the steps in the organization of a unit in the teaching of science.
9. How may the transition from the major problems of a unit to the specific objectives be made?

ADDITIONAL PROBLEMS AND PROJECTS

1. Prepare the organization phase of a unit in a science subject of your choice, including the unit theme, objectives, specific objectives, major problems, pupil activity, teacher activity, and reference materials, supplies, and equipment necessary to teach the unit.
2. Present to the class or prepare a comprehensive report on studies evaluating the unit plan as a method of teaching.
3. Prepare a paper on "There is No Royal Road to Learning."

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8

Administration of a Learning Unit

After the content of a unit has been determined and organized the next step is to decide upon a teaching plan which will achieve maximum efficiency. Several plans are presented in educational literature but close examination reveals very few fundamental differences. The following discussion will present in relative detail a teaching-learning cycle involving five major steps which resemble to a large degree those proposed by Morrison, but which deviate greatly in many aspects. The five basic steps are (1) Exploration or Approach, (2) Planning or Presentation, (3) Assimilation, (4) Organization, and (5) Recitation.

EXPLORATION OR APPROACH

In this initial step of the administration of a learning unit, the teacher and pupils are oriented. This orientation may take place in many ways. According to the Morrison Plan, this orientation or exploration period consists primarily of the administration of a pretest. In other plans, an attempt is made to explore the possibilities of a certain subject area by means of discussion and questioning on the part of the teacher and pupils to see whether or not the unit is worthy of study.

The pretest can be administered either orally or in written form. It may be in the form of an objective mastery examination on the unit which may be given at the beginning as a pretest to see how much the pupils already know about this unit. This same test may be used also as a mastery examination, thereby determining the amount of growth or learning which the pupils have achieved during the study of the unit. If the test is given orally, it is generally in the form of broad questions which are not too factual, but will indicate in general what the class as a whole knows about the unit. This type of question may also be used in a written pretest.

One advantage of a written test, whether it be of the objective or of the subjective type, is that a measure can be achieved for each individual child. With the orally administered pretest, only a measure of the knowledge possessed by the entire class is determined. This does not provide for ministration to the individual pupil. The oral pretest provides for integration of the Approach, or Exploratory phase of the unit, with the Planning, or Presentation phase. It provides also for immediate measure. In the case of the written pretest, it is necessary that these papers be scored or evaluated before any benefit can be derived.

Purposes of the Approach Cycle. The Exploratory, or Approach Cycle, has four purposes: (1) to find out how much the pupils know about the unit before study is begun; (2) to motivate the pupils in the study of the unit; (3) to help orient the teacher and the pupils in the study of the unit; and (4) to make possible an apperceptive approach.

It is important and interesting to find out what the pupils know about a unit before study of it is begun. This makes it possible for the teacher to utilize pupils, who have some advanced knowledge about a certain area of the subject, in the later activities in the unit such as demonstrations, reports, and other contributions. It makes possible also more thorough attention to individual differences in the study of the unit.

The administration of a pretest tends to motivate pupils in the study of the unit because it raises many questions and problems regarding many areas of understanding for which the pupils are eager to find an answer.

Orientation on the part of the teacher is effective in that the teacher finds out what the pupils already know and can use this knowledge in the apperceptive approach, that is, to use what the pupils already know to bring forth new learnings.

PRESENTATION OR PLANNING PERIOD

According to the Morrison Plan of administration of a learning unit, after the pretest has been given and evaluated, the teacher gives an overview of the whole unit which is to be studied. This plan follows the theory of *Gestalt* psychology, according to which the human organism reacts to the whole situation rather than to

parts of it. This overview gives the pupils the total broad picture of the unit and outlines for them the road which they are going to travel.

This Presentation, or overview, may be given in the form of a story or lecture which is supplemented whenever possible in the field of science by numerous demonstrations and illustrations which will help to stimulate interest and give the pupils a better idea of the general theme of the unit. The technique may be largely that of questions asked by the teacher or pupils which are carefully planned and directed so as to cover the entire area. These questions may be answered by other pupils, or pupils who happen to know the answer. If the pupils do not know the answer, the teacher can supply it. Generally, it is found that the question method is more successful with pupils in the lower secondary school grades, and that the lecture method succeeds better in the upper secondary school grades, depending on the age and maturity of the pupils.

The overview may be supplemented with, or may be composed entirely of, a moving picture film which covers the entire unit, a field trip, slides, or may be a talk given by some outside speaker. Units upon which outside speakers may be secured are in the area of conservation, forestry, agriculture, machines, and the like.

Persons who prefer an extensive participation of pupils in planning a unit may utilize this period for pupil planning of the activities of the unit. This type of planning is more successful with a class of brighter pupils and pupils who have had considerable experience in this type of initiative. It has been the experience of the writer that more time is consumed in this type of approach to the unit, but often the extra time consumed is compensated for in the added interest on the part of pupils.

INTEGRATION OF EXPLORATION AND PRESENTATION

In a majority of units in all science subjects it is more practical and functional to integrate the exploratory cycle with the presentation period. As the questions are asked by the teacher for the purpose of finding out what the pupils know about the unit before it is taken up for study, an overview of the unit may be given. Gen-

erally it is found that the pupils can furnish most of the information which makes up the entire story of the unit. A stenographic report of the approach to the unit in general science on *Knowing the Earth* may serve to illustrate the participation of pupils and teacher.

Teacher: What was the theme of the unit which we last studied?

Fred: The heavenly bodies including the solar system.

Teacher: Which one of these heavenly bodies is most important to us?

Arthur: The earth.

Teacher: How many agree that the earth is the most important heavenly body as far as we are concerned? (A large majority of the class of 36 pupils held up their hands.)

Teacher: How many think that we ought to find out more about the earth on which we live? (All hands came up.)

Teacher: Some of the things about the earth which we can learn are: how it was formed, how its surface changes, and how we keep track of time. Can anyone tell us how the earth was formed?

Bernard: The planetesimal hypothesis says that the planets were formed from a collection of smaller heavenly bodies.

Arthur: A comet came along and a piece broke away and it was the earth.

Teacher: Yes, that was an older theory which claimed that the planets, of which the earth is one, were formerly a part of the sun. We find that there are many theories as to the formation of the earth and we must accept the one which seems most reasonable to us. We do not know exactly how the earth was formed but at least it is here. What are some of the ideas about the age of the earth?

Bernard: Experiments on the stages in radium help to tell the age of the earth.

Teacher: Has the earth changed since its formation?

Donald: Islands came in the ocean; part of the Gulf of Mexico fell in and some new lands came up.

Teacher: What has happened to the land?

Donald: It sunk away.

Bernard: I have read that continents are drifting apart.

Teacher: That is most likely due to the sinking of the land between the continents, causing the space filled with water to become wider. It is true, is it not, that there is rock all around the earth. Therefore, islands are merely what?

Charles: Mountains sticking up above the water.

Donald: Is it true that some islands move or float about?

Charles: They are made of something so they float; soft sand or something.

Fred: Animals die and attach themselves together, forming an island.

Teacher: What kind of animals are these?

June: Corals.

Teacher: Yes, coral reefs are numerous in the shallower portions of the ocean, especially where there are a large number of islands. These coral islands and reefs are made up of the skeletons of millions of corals. These coral reefs are a source of great danger to shipping and ships which sail in the ocean because many of the reefs are under the surface so ship captains cannot see them.

Arthur: Will meteors hit boats? I read once that a meteor went right through a boat and it sank. Is that true?

Teacher: Yes, that would be possible, but rarely happens.

LaVerne: Animals make coral trees and divers get these trees and sell them.

Teacher: Yes, you may go to Florida and the South Seas and see these coral trees and the reefs in the beginning stages. How does the surface of the earth change?

Pearl: The chief ways are by glaciers, erosion, and volcanoes, and all other eruptions change the surface of the earth.

Teacher: What causes shifts in the earth?

Pearl: The earth crust falls at the weakest place and this causes earthquakes and volcanic eruptions.

Teacher: Yes, contraction of the earth, also, causes this as well as unequal weight on the surface due to shifting of soil from erosion, rivers, and volcanic eruptions. A good example to show how the earth changes due to contraction is to take an apple and allow the moisture to evaporate from it. The skin wrinkles because the material under the skin has shrunk. On the earth, what would correspond to the wrinkles?

Bernard: The mountains and hills.

Teacher: Yes, the shrinking causes strains and stresses in the crust which makes some parts rise while other parts are lowered. This process is called diastrophism. (Teacher writes the word on the board.)

Arthur: Will the earth shrink so that there isn't anything?

Teacher: No, the shrinking process is very slow, taking millions of years to shrink a very small amount, and there most likely is a point where this process will stop. I might tell you about something which we studied in college. A geologist took us on several field trips during which we studied changes in the earth's surface. On one trip, we studied the area around Lake Superior where the cities of Superior, Wisconsin, and Duluth, Minnesota, are located. We were told that the land at the head of the Lakes where these two cities are located is sinking at the rate of 3 inches per 100 years. Therefore, in 10,000 years the land would sink approximately 25 feet and the land upon which Superior is built will be largely under water if the land continues to sink at that rate.

On the Duluth side of the Bay, a former shoreline of Lake Superior can be seen which is located on a 600-foot bluff about 400 feet above the present

level of the Bay. The city of Duluth has constructed a scenic highway along this ancient shoreline. This bluff was caused by a fault in the earth. Faults are caused from rocks slipping downward for distances ranging from a few feet to several hundred. One can recognize a fault by looking at the rock layers. (At this point, the teacher sketched illustrations on the blackboard.) These faults often cause severe earthquakes. How many have seen the layers of limestone and sandstone on the bluffs around our city? (Most of the pupils raised their hands.) This limestone and sandstone were deposited there under water many thousands of years ago. The limestone is made up of shells of water animals and sandstone is made up of sand which has been pressed together by the weight of the earth deposited above the layer during the years that followed.

Fred: The earthquakes in California were caused from faults in the ocean and the quakes also caused many smaller faults in the surrounding country.

Arthur: I read that there is land below the ocean.

Teacher: Yes, there is.

Arthur: Why don't they build a railroad above the ocean? It would be quicker that way.

Teacher: The ocean is too deep, in places running up to two or three miles.

Donald: Could anyone build a big tunnel under the ocean?

Teacher: I suppose it could be done, but I am afraid that the tremendous weight of the deep water in places would crush the tunnel. It would not be practicable. Let us take a cross section of the earth's crust from Asia due east to the Atlantic Ocean. (The teacher draws this on the board indicating water levels.) A tunnel could probably be built from Asia to Japan. What is this peak sticking above the ocean midway between Asia and the United States?

June: The Hawaiian Islands.

Teacher: That is correct. What is the projection here?

Clifford: The Rocky Mountains.

Teacher: The dip here?

Rose Mary: The Mississippi River.

Teacher: The protrusion here?

Charles: The Appalachian Mountains.

Teacher: Do the shifts of the earth's surface sometimes do good?

Bernard: Yes, it makes harbors.

Teacher: The harbor at Duluth and Superior which we just mentioned was formed that way. Shifts in the earth also form beauty. Most of our National Parks are natural beauty due to these causes. Yellowstone is due to volcanoes; the Grand Canyon, to erosion and diastrophism; and Glacier Park is due to diastrophism and erosion. We should read up on these parks and make reports to the class on them. How many have been at any one of these parks? (No hands.) You must go at your first opportunity. I made a trip to nine of these parks one summer and it cost four of us only $41.50 each.

The best example of the effect of volcanoes is that of Mt. Rainier in Washington State. This mountain was formed by volcanic eruption and towers

14,000 feet above the surrounding country. It is snow-covered the year round. It is only 75 miles from Tacoma which is located on an arm of the Pacific Ocean. In order to drive around it one must go about 300 miles. There are 12 glaciers on Mt. Rainier which are as deep as our Granddad's Bluff. They are continually melting, and rushing streams flow down all its sides.

Arthur: Is lava coming out yet?

Teacher: No, but there are places where steam comes out. It is not building up any more.

Donald: What is wearing it down?

Fred: Glaciers.

Arthur: There are volcanoes in Japan and Hawaii. I read about a farm falling in. What caused that?

Teacher: That farm fell in because there were caves underneath which were formed by underground water.

Bernard: There are many old volcanic craters in the earth and in the United States. The moon has many huge craters which were formed from lava eruptions. These craters stay the same because the moon has no atmosphere.

Donald: There are many large caves. There is one over at Harmony, Minnesota.

Teacher: Our discussion period has been very interesting and we have had some excellent contributions. Many of us seem to know a great deal about this unit. How many would like to spend the remainder of the period in finding out more about the surface of the earth? (A majority of the pupils raised their hands in approval.) Our first problem is what?

Mary: The changing surface of the earth.

Teacher: That is correct. It is about glaciers, volcanoes, mountains, etc., which will be very interesting if we all do our part. Please be ready to announce the special reports for which you will be responsible during class period tomorrow. A list of suggestions is given on your study sheet. There are many references and booklets on the reference shelf in the back of the room.

ASSIMILATION PERIOD

The third step in the administration of a unit is the Assimilation Cycle, in which the actual learning takes place. This consumes, in most cases, at least three-fourths of the time devoted to the unit. During this time, practically any type of activity may be used which is employed in various types of classes. In a class in science, activities such as reading in the textbook, reference reading, experimentation, field trips, showing of moving pictures, giving reports, and class discussions may be utilized during any period when it seems to be the opportune and more efficient activity to pursue.

Guide Sheets. Successful administration of the Assimilation period usually necessitates the use of study guides. In order to provide adequately for individual differences, it is necessary that study guides be supplied so that pupils may pursue the unit according to their own speed; hence, questions and directions which help the pupils do their work more efficiently should be provided for each pupil. A good guide sheet generally possesses the following characteristics: First, it should contain the statement of the unit theme, or possibly the major concept which states in a few sentences the main idea set forth in the unit. Second, it should contain definite directions which the pupil may follow without help from the teacher. Third, the exercises and questions should be clear and definite, and should bring out the major points or the most important points which the pupils should know. And fourth, it should contain a liberal amount of supplementary activities from which the pupils may choose. It should be understood that the supplementary activities are merely suggestive and, if the pupil can create his own choice, it is probably more desirable, providing it is related to the unit and is significant.

It is desirable that the study guide be as brief and concise as possible. Lengthy and involved questions and elaborate directions which consume space and reading time should be avoided.

The Assimilation period may follow certain definite patterns which may or may not be successfully employed on successive days. With pupils in the junior high school, it has been found more effective to vary the procedure during a single period. A typical procedure during a single period may include the following steps: First, a summary of the program and assignments at hand may be the thing to do. Second, there may be a discussion of difficulties and problems which evidenced themselves during the preceding period, or problems which pupils bring to the class. Third, demonstrations or reports which the pupils may have prepared should be presented. And finally, during the remainder of the period, if it is not too short, pupils may continue with their individual activities.

It is often possible and desirable to continue study or individual work on activities during one whole period or even two successive whole periods. This procedure is progressively more suc-

cessful as the pupils are older. In general, however, a change in procedure produces more efficient results providing the change is not so frequent in occurrence as to disturb the continuity of the child's thought and activities.

Experience has shown that the average ninth-grade class seldom maintains active attention for more than 20 minutes during a discussion. It has also been found that the average ninth-grade class rarely continues with effective study for much more than 40 minutes. It is obvious, then, that the teacher should plan his work so that these facts can be cared for during the class period.

PROBLEM PRESENTATION. As each unit is divided into problems it is necessary to have problem presentations or previews. A majority of units have from two to five problems each of which consumes the attention of the average class for approximately one week in order properly to master the content.

These problem presentations are similar to the unit presentations and give an overview of each problem. They differ, however, in that they are confined to the problem at hand and should penetrate into the detailed portions of the problem. The presentations may be enriched by demonstrations, pupil and teacher questions, pupil reports, and the like. Suggestions and directions as to methods of study and research in solving the problems at hand should supplement the presentations.

While pupils are working on a unit it is preferable to encourage them to confine their activities to the problem at hand. Pupils should be encouraged to engage in enriching activities on the problem rather than to project into the next or future problems. This procedure makes it possible for all pupils in the class to begin the new problem at the same time. In classes of 15 or more pupils it is practically impossible for one teacher to handle a class adequately unless pupils are brought together at the beginning of each problem. This is contrary to the Morrison idea, but efficient teaching is difficult when individual pupils in a large class are so varied in accomplishment that group teaching can not be employed. In the public school class of average size, from 25 to 35 pupils, group teaching must be used in order to keep adequate control of the teaching situation. It is difficult for a teacher to adequately teach and supervise so many pupils individually.

The study on the unit should continue until the slower pupils have completed the minimum essentials of the unit, or until the interest of the class lags. If the interest continues, the unit should be closed when the minimum essentials are completed by the slower pupils, but if the interest lapses, it is desirable to close the unit regardless of the accomplishments unless interest can be revitalized through some special activity such as a field trip, movie film, special demonstrations, etc. A resourceful teacher, however, can do a great deal to maintain interest in the unit at hand until a satisfactory growth is achieved. Generally, it is desirable to announce to the pupils two or three days in advance when the unit will be closed, so that they will have an opportunity to complete the tasks which they have begun, and can plan their work accordingly.

Testing. According to the Morrison Plan, the mastery test should be given as soon as the pupil has completed the work outlined for the unit, and if the pupil does not pass the test, he should be required to do more study and then repeat the test.

The writer's experience has shown that it is an impossible task for the teacher to administer a test in this manner, especially when there are many pupils. A practice which is found to be very satisfactory is to administer an objective examination on the unit to the whole class when the unit is closed, according to the plan described in the previous paragraph. This provides for one administration of the test to every pupil in the class and reduces the amount of detail work on the part of the teacher. In the case of general science, retesting and remedial work are rarely practical because mastery of any one area is not necessary for future preparation. In physics and chemistry, however, it may be somewhat different. Even in these subjects, it has been found possible to do remedial work in the succeeding units after pupils who are deficient have been discovered through personal contact, analysis, and results of the examinations.

If objective examinations are employed, it is possible and desirable to have the pupils assist in checking of the examination papers, thereby saving the teacher a great deal of routine work. A plan can be devised which is efficient enough for practical purposes. The merits and demerits of this plan of checking examination papers will be discussed in a later chapter.

ORGANIZATION

According to the Morrison Plan, Organization is a fourth step in the administration of a unit. The plan is that pupils organize what they have learned without reference to any textbook or materials from which they secured their information. This organization should be the pupil's own work which he carries out according to his own plan. It is really a summary of the unit. This summary is in written form and may consume from 20 minutes to more than a period, depending upon the length of the unit and the extensiveness of the organization.

Other plans employ this organization as a review which is done before the mastery test is given. Under the Morrison Plan, however, it is not considered as a review, but a reinterpretation and a refixing and clinching in the mind of the pupils of material which has been covered. Generally, no evaluation or grading is given on this organization material. A teacher should feel privileged to do so, however, should such evaluation be a motivation for the pupils. It has been the experience of the writer that in the majority of cases pupils do this work for its own sake if they have been trained in that manner, and if overemphasis has not been placed on grading.

This organization may be done individually or in committees. Occasionally, the unit is of such size that organization of the total material consumes too much time and evidences less satisfactory results in the Recitation, or last phase of the administration of the unit. Occasionally, there are three or four problems in a unit. This makes it possible for the class to organize itself into three or four committees; or if the pupils are seated at tables with four pupils at a table, each table may be a committee and each member of the committee may take a portion of the unit for organization.

RECITATION

During the Recitation phase, certain pupils are given an opportunity to summarize orally before the whole class the learning acquired during the study of the unit. As suggested in the previous discussion on the Organization, this Recitation may be done by a certain committee whose members have taken certain portions of the summarization, or by several committees if each committee has taken a portion of the summarization. If each pupil summarizes a

whole unit, then one pupil will give his summary of the unit, and other pupils will be ready to criticize and add to it. In case all pupils summarize a whole unit it is frequently wise for the teacher to call upon that pupil for first recitation who has a very short or incomplete summary. This provides an opportunity for many more pupils to participate in the criticism and additions to the summary given than would otherwise be the case. For if a bright pupil who has a comprehensive and complete summary is called upon, it affords less opportunity for other members of the class to contribute these additions and make criticisms.

Obviously, under this plan very few pupils get an opportunity to recite during a semester; hence the teacher should be careful to distribute this opportunity. The purpose of this recitation is to fix further in the minds of the pupils the learnings which they have achieved in the study of the unit. It also provides opportunities for oral expression on the part of the pupils, and for additional critical thinking on the part of all the pupils.

A brief plan for the administration phase of a unit in General Science on *Beyond the Earth* may help to illustrate more clearly how this technique operates.

UNIT VII—BEYOND THE EARTH

Unit Administration

I. Exploratory cycle or approach:
   A. Objectives.
      1. To discover what pupils already know.
      2. To motivate further study.
   B. Procedure: Administration of the following pretest orally. Short discussions should be held on questions brought up by pupils, emphasizing importance of getting final answers while studying the unit.
      1. What is the nature and origin of the earth?
      2. What is a planet? Is the sun a planet?
      3. Do all planets revolve around the sun?
      4. Of what is the sun composed?
      5. How many kinds of heavenly bodies are there?
      6. How many planets are there? Name as many as you can.
      7. What is the moon? What causes it to change appearance?
      8. What is the difference between stars and planets?
      9. What is a constellation?
      10. Name some constellations. How did they get their names?
      11. Do the stars move?

12. How could you find a particular star?
13. Do you know of any manner in which the earth is affected by heavenly bodies? Are people affected?
14. What causes changes in season?
15. What time is it now in New York? In China?
16. How do we find ''correct'' time?
17. Does the sun always rise in the east and set in the west?
18. What is an eclipse?
19. Do you think there is any danger of the earth's being hit by another heavenly body?
20. Would you like to be an astronomer?

II. Planning cycle or presentation:
  A. Objectives.
    1. To give the pupils an overview of the unit.
    2. To motivate study.
    3. To give some appreciation for the wonder of the universe.
  B. Procedure: Give the following presentation:

We usually think of the stars as being far away and not affecting our lives very much, but study of their movements has come to be of great importance to all of us. The day upon which your next birthday will fall, for instance, depends upon the movement of heavenly bodies. Important as this subject is, it was not until comparatively recent times that much was known of it. Before men learned what stars really were and what governs their movements, they invented myths and superstitions to explain what was for them a great mystery. Many of these superstitions grew into religions. I am sure that all of you have read at some time of sun worshippers. The early Greeks and Romans named the stars for their gods and goddesses, of which they had a plentitude. By the time of the Middle Ages, enough observations had been made of the movements of stars and planets for learned men to be able to tell when a star or planet would appear in a certain section of the sky. It was at this time that the superstition of astrology was popular. People believed that their lives were determined by the position of the stars in the heavens at the time of their birth. We know today that there is no truth in this superstition. It was not until men began to search for reasons in the heavens that the science of astronomy was born. The principle of the telescope was discovered by a Dutchman named Hans Lippershey, in 1608, and Galileo, an Italian of the same period, developed it into an instrument with which he was able to study the heavens more closely. To men the sun and moon are of course the most important of the heavenly bodies because they are the closest and best known. But the sun cannot be said to be very close to us for it is 92,000,000 miles away from the earth. Around the sun revolve the earth and other planets, and beyond the sun and planets lies the immensity of the universe where distances are too

great to be measured by miles. Out there, the speed of light which travels 186,000 miles a second, is used to measure the space between bodies. Light from the nearest star, Aldebaran, requires 44 light years to reach the earth. The actual effect of heavenly bodies on the earth, distant as they are, is felt in changes of season, tides, and many other ways.

III. Assimilation (6½ periods)—See Guide Sheet:
- A. Last half of second period.
  - 1. Objectives.
    - a. Acquiring of knowledge.
    - b. Interest in organization of universe.
  - 2. Procedure.
    - a. Present Prob. 1.
    - b. Hand out guide sheets and discuss assignments.
    - c. Begin plans for topics and projects.
    - d. Supervised study on Prob. 1.
- B. Third period.
  - 1. Objectives.
    - a. Knowledge.
    - b. Appreciation of mysteries of space.
    - c. Appreciation of scientific method in learning facts about the universe.
  - 2. Procedure.
    - a. Class discussion on how universe is organized.
    - b. Special topics if ready, and plan for further topics and projects.
    - c. Supervised study.
- C. Fourth period.
  - 1. Objectives.
    - a. Knowledge.
    - b. Appreciation for beauty of stars.
    - c. Attitude of awe toward order in the heavens.
  - 2. Procedure.
    - a. Follow-up on topics and projects.
    - b. Discussion on the nature of the heavenly bodies.
    - c. Supervised study.
- D. Fifth period.
  - 1. Objectives.
    - a. New knowledge.
    - b. Clarify old knowledge.
    - c. Find out where corrective measures are necessary.
  - 2. Procedure.
    - a. General review and discussion of Prob. 1.
    - b. Follow-up on projects and reports.
    - c. Supervised study. Complete work on Prob. 1.

E. Sixth period.
  1. Objectives.
    a. Knowledge.
    b. Present Prob. 2.
  2. Procedure.
    a. Topics.
    b. Preview of Prob. 2. Secure additional topics.
    c. Supervised study on Prob. 2.

F. Seventh period.
  1. Objectives.
    a. Knowledge.
    b. Appreciation of effect of celestial movements on the earth.
  2. Procedure.
    a. Topics on Prob. 2.
    b. Discussion on how the earth is affected by other heavenly bodies. Demonstration on seasons.
    c. Discuss topics and projects on Prob. 2.
    d. Supervised study on Prob. 2.

G. Eighth period.
  1. Objectives.
    a. Knowledge.
    b. Review.
  2. Procedure.
    a. Follow-up on topics.
    b. General review on what has gone before; demonstrate phases of the moon.
    c. Clear up questions; offer remedial work; complete work on Prob. 2.

H. Ninth period.
  1. Objectives.
    a. Find out what pupils have learned—degree of mastery.
    b. Evaluate teaching.
  2. Procedure.
    a. Administer mimeographed mastery test on unit—about 30 minutes. (See test on last page.)
    b. Have pupils exchange papers and score test.
    c. Discuss test and remedial work. (10 minutes.)

IV. Organization. (Tenth period.)
  A. Tenth period.
    1. Objectives.
      a. To organize and summarize material taught during the unit.
      b. To aid pupils in understanding and retaining functional part of unit.

2. Procedure.
    a. Have each pupil write an organized summary of the information acquired in the unit without any references. (About 30 minutes.)

V. Recitation.
  A. Last part of tenth period.
    1. Objectives.
      a. Further to clinch materials of the unit.
      b. Give pupils opportunity for self-expression.
      c. To have pupils hear the story of the unit retold.
    2. Procedure.
      a. Ask for volunteer to give the summary to the class or call upon pupil.
      b. Have rest of pupils supplement omitted material and criticize the summary.

GENERAL SCIENCE STUDY SHEET

Unit VII—Beyond the Earth.

Unit Theme: The earth is an insignificant part of the universe.

Assignment: Write out the questions at the beginning of the two chapters, then the questions on this sheet, and finally the questions at the end of each chapter.

Central Idea: The earth is a small part of the solar system and the solar system is one of millions like it in the universe.

Problem One: What do we find in going through space with the astronomer?

Assignment A.

1. Why did ancient man study the sky?
2. What is the difference between astronomy and astrology?
3. What are constellations? How did many of them get their names?
4. How far from the sun is the earth? Mercury? Neptune?
5. Why might we receive light from stars destroyed 100 years ago?
6. What makes up our solar system?
7. Make a statement giving some idea of comparative size of different stars.
8. What is the Milky Way?
9. Although the stars are constantly moving, why can we observe no change in their position over a period of years?
10. If any stars are constantly moving, besides our sun, why have astronomers not discovered them?
11. Give two statements about the size of our solar system.
12. What are the stars like? Give examples of densities, etc.

Assignment B.

1. What is the theory of the origin of our solar system? (Hogden, p. 470.)

2. List five things you know about our solar system that the ancient people without telescopes did not know.
3. Why do intelligent people no longer regard astrology as science?
4. After whom did the Greeks name the planets?
5. What is the idea of wet and dry moons that some people have?
6. What is the first important invention that helped astronomy, in 1608? Who invented it? (Pieper and Beauchamp, p. 4.)
7. What other man later made a telescope? What country was he from? (Pieper and Beauchamp, p. 4.)
8. Why do ships disappear from sight when they go out to sea? What part of the ship will disappear last? (Pieper and Beauchamp, pp. 6–7.)
9. Give two reasons why scientists believe that the earth is a sphere? (Pieper and Beauchamp, pp. 6–7.)
10. Using the information found in your text, calculate the distance in miles from the earth to the Pole Star.

Assignment C.

1. Give a report on one of the following:
   a. Origin of the solar system. (Hogden, p. 470.)
   b. Sun spots and the moon. (Hogden, pp. 463–466.)
   c. Early astronomy. (Pieper and Beauchamp, pp. 1–5.)
   d. Why heavenly bodies move in definite orbits. (Pieper and Beauchamp, p. 22.)
   e. On the immense lens which has just been made.
   f. Any other report from a current magazine that is suitable to work on our unit.
2. Make the drawing on p. 149 in "Our Surroundings."

Problem Two: How is the solar system made up?

Assignment A (Solar System).

1. Just what do we mean by the "solar system"?
2. What kind of a path does the earth take through space?
3. What is meant by gravitational attraction? Explain.
4. Of what is the sun made? What is its surface temperature?
5. What is the explanation of sun spots?

The Planets:

1. What three resemble the earth?
2. Name the smallest and the largest planet?
3. What planet is most similar to the earth? Explain.
4. What do we mean by the "inclination" of the earth? What effect does it have on us?
5. Explain the difference between rotation and revolution in regard to the motion of planets.

The Moon:

1. Why does the moon have differences in temperature?
2. Why is it no doubt true one would weigh less on the moon?

3. Why does the moon appear to change shape?
4. Describe briefly the surface features of the moon?
5. For how many nights does the moon stay full?

Eclipses and Tides:

1. In what position of the moon do the so-called "spring tides" occur? Prove your answer.
2. What is a tidal wave? an earthquake wave?
3. What kind of an eclipse can take place when the moon is "new"? Explain why.
4. Is a solar eclipse visible over the whole earth at the same time? Explain why or why not?
5. Does an eclipse ever take place that we do not notice? Which kind of an eclipse, if any? Explain.

Assignment B. Write *clear, good* answers to the following:

1. Define the meanings of the following: lunar, satellite, solar, eclipse, terrestrial, orbit, crescent, comet, meteor, axis.
2. Why do planets travel in elliptical orbits rather than in straight lines?
3. What is the relation between the density of the various planets and the weights of objects on them?
4. How did astronomers know that Neptune existed before it was discovered?
5. What is the position of the moon during "neap tide"?
6. What is a lunar month? How many phases has it?
7. Why are two high tides caused at the same time on opposite sides of the earth?
8. What is there peculiar about the planet Saturn?
9. Between what two planets do the asteroids revolve about the sun? What are planetoids?
10. Draw a diagram on p. 154 in "Our Surroundings."

Assignment C.

1. Prepare and demonstrate before the class one or more of the following: Experiment 34, p. 257; project, p. 261; Experiment 35, p. 268; report on p. 281.
2. Prepare reports which can be given to the class or presented in written form without class report. Some suggestions are: any one, or in general, about meteors, meteorites, planets, comets, telescopes, or others related to this unit.

MASTERY TEST—BEYOND THE EARTH

Please place an (O) before each false statement and a (+) before each true statement.

1. It was more important for early man to know the heavens than it is for us to know them.
2. Astrology contains a little astronomy.

3. Astronomy developed out of astrology.
4. We know of nothing which travels faster than light.
5. The sun is our closest star.
6. The sun is the largest star of which we know.
7. All stars have planets revolving around them, as does our sun.
8. Our sun is part of a great galaxy.
9. A heavenly body is luminous when it attracts other bodies by gravitation.
10. There were no astronomers before telescopes were invented.
11. Mercury is nearest the sun, while Pluto is farthest away.
12. The sun is the star most useful to us.
13. We can believe only a few of the better informed astrologers.
14. The Greeks were our first real astronomers.
15. The conditions of life on the other planets still remain one of the greatest mysteries of the universe.
16. We are sure that the densities of all planets and stars are the same.
17. The Milky Way is a galaxy.
18. Our solar system occupies only a very small part of the space astronomers have explored.
19. Men have always studied the sky.
20. The telescope is valuable only for studying those planets not visible to the naked eye.
21. It is possible that some starlight reaching the earth comes from stars not now in existence.
22. Most suns are extremely hot.
23. All suns in a galaxy are moving in response to the gravitation of other stars in the group.
24. A nebula is a luminous cloudy patch in the sky.
25. Our sun is a member of an important galaxy.
26. There are only a few galaxies in the heavens.
27. The telescope is the astronomers' most useful instrument.
28. Our solar system consists of our sun and all of the heavenly bodies of various kinds that revolve around it.
29. The paths which the planets follow in revolving around the sun are egg-shaped or elliptical.
30. The sun is a hot gaseous body with surface temperature of about 10,000° F.
31. Our sun is only one of many stars we can see in the heavens.
32. Of all the planets the largest and closest to the sun is Venus.
33. The moon, because it is a gaseous body, gives off its own heat and light.
34. All the planets have one or more moons called satellites.
35. There is no life on the moon because it has no water or atmosphere.
36. When the moon is on the opposite side of the earth from the sun we may have an eclipse of the sun.

37. Tides are the movements of ocean waters due to the gravitational attraction of the moon and sun for the earth.
38. The earth revolves around the sun once in 365½ days and this interval of time we call a year.
39. Tides are the movements of ocean waters due to the gravitational attraction of the moon and Jupiter for the earth.
40. Of all the planets, the one most likely to sustain life is Mars.
41. Between the orbits of Jupiter and Saturn are bodies, much larger than the planets, called asteroids.
42. Jupiter is sometimes called the giant planet because it is larger than the sun through a telescope and farther from it than any other.
43. Saturn is distinguished from other planets when seen through a telescope in that it has three rings around it.
44. Neptune was discovered because its attraction for Uranus caused Uranus to swerve or vary in its motion.
45. Meteors are small bits of matter pulled to our earth which when they reach our atmosphere are heated by friction so that they usually burn.
46. Parts of meteors which reach the earth's surface as solid fragments are called meteorites.
47. Meteors are believed to come from comets which have broken up and become scattered through space.
48. Sun spots are regions of clouds on the sun which hide the sun's true surface from our sight.
49. Without the energy that the earth receives from the sun, life on earth would be impossible.
50. In regard to the origin of our solar system, most scientists accept the planetesimal hypothesis.

Please fill in the blanks:

51. Each of the bodies in our solar system follows a path known as an ....around the sun.
52. The temperature at the surface of the sun is much................................ than any produced on the earth.
53. By the use of an instrument known as a................................we are able to learn the elements of which the sun is composed.
54. The sun is composed chiefly of metals and the gases................................ and................................
55. There are no known................................in our solar system.
56. We can see the planets because they............................the.............................
57. The terrestrial planets are................................than an equal volume of water.
58. The orbits of the planets are almost perfect................................
59. ....is the planet nearest the sun.
60. Venus is called the................................twin because of the size and the conditions on the planet.
61. At full moon we see the lighted................................of the moon.

62. The .... is the chief cause of the tides, although the .... is a less important cause.
63. It is believed that Mars has an .... but .... is probably the only life on this planet.
64. Small globes, many of which are revolving about the sun between Mars and Jupiter, are known as ....
65. Huge stones which fall through our atmosphere to earth are called ....
66. Saturn is .... in size among the planets and is perhaps the most beautiful because of its .... rings.
67. The friction of the air causes meteors to ....
68. A tiny body which moves as the planets do but which gets nearer the sun and then develops a tail or streak of light is called a ....
69. Meteors are now thought to be parts of .... which are attracted toward the ....
70. Most meteorites are composed of .... but a few are almost pure ....
71. .... is a science.
72. .... is not a science.
73. Astrology was established in the days of ancient ...., which was about .... B. C.
74. Astronomy grew out of ....
75. The first people who attempted to classify the heavenly bodies and to explain the facts of astronomy were the ....
76. Two inventions of great importance to astronomers were the .... and the ....
77. Our earth is one of a family of .... planets.
78. The circular path that the planets use in revolving about the sun is known as their ....
79. The planet nearest to the sun is .... It would take an express train traveling at 60 miles per hour .... years to go from the sun to Mercury.
80. Our solar system occupies a .... part of the heavens.
81. Light travels .... miles in one second.
82. Smaller, nongaseous stars usually weigh .... than gaseous stars.
83. The size of our sun is ....
84. An observer at the time of Christ and an observer at the present day using the naked eye, would notice .... in the position of the stars in the heavens.
85. We may still be receiving light from stars that are not in ....
86. Our sun is more than a million times .... in size than the earth.
87. The Milky Way is made up of millions of ....

88. The broad bank of light extending across the heavens is known as the Milky Way or........................ ......
89. Our sun is one of the smaller................................in the galaxy.
90. The stars in a galaxy are...............................miles apart.
91. Very few, if any, suns are surrounded by...............................other than ....sun.

Matching Test

92.	1. Planet.	1. The Milky Way.
93.	2. Meteorite.	2. The distance light travels in one year.
94.	3. Galaxy.	3. Attraction between bodies.
95.	4. Constellation.	4. A heavenly body which reflects light.
96.	5. Light year.	5. Attraction toward the earth.
97.	6. Astronomy.	6. A meteor which strikes the earth.
98.	7. Astrology.	7. A group of stars.
99.	8. Gravity.	8. Nonscientific study of the stars.
100.	9. Gravitation.	9. The path of a heavenly body.
101.	10. Orbit.	10. A single star.
		11. Scientific study of the heavenly bodies.
		12. 186,000 miles per second.

102. Define: moon, total eclipse, partial eclipse, tide, neap tide, spring tide, meteor, comet, planetesimal hypothesis, planetoids.
103. Name: 9 planets, 1 galaxy, 5 constellations, 4 phases of the moon.

STUDY QUESTIONS

1. What are the problems of the Approach Cycle, the Presentation or Planning Period, the Assimilation Period, the Organization, and the Recitation?
2. Discuss the different types of tests which may be used in the Exploration Period.
3. Give the characteristics of a well-planned presentation.
4. How many pupils help in the planning of a unit?
5. What are some of the more important activities which may take place during the Assimilation phase of the unit?
6. Give the more important characteristics of a good study guide.
7. Discuss the span of attention as a factor in determining the procedure of teaching.
8. Discuss the relative merits of individual mastery testing versus administering a test to all pupils at the same time.
9. What is the procedure in the Organization phase of the unit?
10. What is the procedure in the Recitation phase of the unit?

ADDITIONAL PROBLEMS AND PROJECTS

1. Prepare a plan for administering a unit in a science subject of your choice. Include detailed directions for each day, complete study guide, and a mastery test.

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9

Other Methods of Teaching

Numerous techniques in teaching have been developed and identified with descriptive names over a period of time. Among the more commonly used methods may be placed the lecture, question and answer, reference, contract, flexible assignment, project, and laboratory. The unit plan permits integrative use of all these methods as a whole or in part whenever appropriate. An attempt will be made briefly to describe and evaluate these techniques as applied to the teaching of science.

Lecture Method. In the lecture method, the teacher imparts to the learner by word of mouth the knowledge which the former possesses and the latter lacks. This method is still widely used, not only formally in public lectures, but informally in conversation and in the home where older members of the family teach the younger. This method of teaching is rapidly vanishing from our secondary schools, but is, unfortunately, still too predominant in our schools of higher education. The efficiency of the lecture method is found to be dependent upon the ability of the learner. It is thought to be less effective for the average or below average pupil than for the above average and superior pupil.

Generally, in the secondary school, it is considered a sound principle to practice the following: "Do not tell your pupils these things; get them to tell you." This means that it is necessary for teachers to furnish source materials and guide them in securing the information. When employing the Unit Plan a lecture may be quite effectively used during the Presentation Cycle. The teacher may tell the pupils a story of the unit, thereby giving them an overview. Experience has shown that this type of presentation is less effective with pupils of the junior high school level and becomes increasingly effective with pupils in the upper grades of the high schools. In the lower secondary school grades, such as junior high school, and probably running through the tenth grade, and to a certain

extent in the upper grades, it is wise to inject a certain amount of questioning, especially when attention seems to lag. The injection of pertinent questions to which members of the class or the whole class can respond may tend to recapture their interest or continue to hold it until the total presentation has been given. Preston[1] gives a list of strong and weak points of the Lecture Method:

Strong Points	*Weak Points*
1. It is cheap. No special apparatus required. Size of class is practically unlimited.	1. No assurance that audience is attentive and is receiving what is given.
2. Rapid. More ground can be covered in a given time than by any other method.	2. No assurance that what is received is understood.
3. Generally involves less preparation on the part of the teacher than does other work.	3. Rate may be too rapid to allow hearers to get necessary connection of thought.
	4. Pupils are unskilled as listeners.
	5. Pupils are passive recipients, not active participants.
	6. Minimum stimulation to critical evaluation; emphasis on content retention above all else.

Many authorities in the field of teaching tend to advocate an increased use of the lecture method in the upper secondary school grades, especially for the pupils who are planning to attend college. The obvious reason for this is that it may tend to orient pupils better for college because this method is predominant in the college of today. Other authorities advocate that the college should change its method, but experience shows us that such a change in the method of teaching in college is difficult to achieve.

Along with the use of the lecture method, it is advocated that practice in effective note-taking be given to the upper classmen of our secondary schools. Learning to take notes while reading reference books and textbooks should be of considerable value for pupils in high school and in college. Improvement in this skill may be effectively realized by special attention given to it on the part of the teacher. During the supervised study period, the teacher may critically check and observe the outlining and note-taking of pu-

[1] Preston, C. E.: "The High School Science Teacher and His Work," New York, McGraw-Hill Book Co., Inc., 1936, p. 144.

pils, and at times discuss individually or collectively means by which this work may be improved.

Question and Answer Method. The question and answer method is a device whereby the teacher, by his questions, attempts to bring out information which the learner already possesses and to organize it in the pupil's mind to serve as a basis for understanding the new knowledge to be imparted. This method may be used as an approach to other methods of teaching, and can be extensively used in the exploration or approach phase of the unit plan described in the previous paragraphs.

The question and answer method can be very effectively employed during the discussion periods in the Assimilation phase of the unit. Questioning is an art and usually requires many years of experience to effect its perfection. A teacher may employ a check list which contains criteria for the evaluation of the method of questioning used. Items on this check list may be as follows:

1. Are the questions clear and distinct?
2. Are they thought-provoking?
3. Do they keep the discussion pointed toward the objective?
4. Do they require long rather than short answers?
5. Are they evenly distributed throughout the class?
6. Are they adapted to the current situation in the class; that is, do they follow through significant and related areas of information which are brought up by the pupils?
7. Are the questions adapted to the ability of the individual child?
8. Are they adapted to the grade for which they are used in terminology and content?
9. Do the pupils respond enthusiastically to the questioning?

It may be wise for the beginning teacher to bring to class a written copy of a well-planned set of questions during a discussion period. At times, this plan is acceptable also for the experienced teacher. Nevertheless, the teacher should attempt to get along as much as possible without referring to the set of questions because constant use of such a prepared worksheet tends to slow up the classwork, makes the discussion too rigid, and may cause pupils to feel that the teacher lacks mastery. Even with a rather close ad-

herence to a sheet of prepared questions it may frequently be wise and effective to digress from the prepared questions with questions that come up during the discussions.

A teacher should keep in mind certain cautions during a discussion. There are two extremes between which it is safer to keep the trend of this type of class period. One of these extremes is to hold so narrowly to a given plan that all pupil-originated questions and volunteer statements are kept out. This tends to destroy pupil interest and enthusiasm for participation. The opposite extreme is to permit diverse questions too freely, eventually leading the discussion entirely off the track. In certain types of questions and answers where the questions are concerned primarily with checking on the daily preparation of the pupils, it often occurs that members of the class purposely divert the teacher's aim so that their lack of preparation might not be discovered. In the use of the unit plan, however, its proper pattern practically eliminates this type of deliberate forcing off the track, because generally the questioning is not for the purpose of checking the pupil's preparation in an assigned lesson, but to stimulate thinking and interest in further study on the unit.

The Reference Method. The Reference Method is used quite extensively in the teaching of science and can be incorporated into the unit plan during the assimilation period. In general, the plan operates as follows:

The pupils, with the help of the teacher, decide upon a topic or unit to be studied, and the pupils use several references to solve this problem at hand. The pupils may be given a mimeographed study guide which contains guiding questions to be answered. Instead of finding these answers in a certain textbook, many different reference works, not only in the same subject but in other subjects as well, may be used. For example, in a unit on Air, reference books may include textbooks on physics, chemistry, biology, physiology, general science, as well as encyclopedias, etc. This method is claimed to be effective in training pupils in the skills of locating reference material and solving problems.

The efficiency of this method in the teaching of science may be challenged on the ground that it may be uneconomical, especially for average and slow pupils, because it entails a great deal of dupli-

cative reading and the reading of material for a clear understanding of which the pupil's background may be inadequate. For example, if a ninth-grade pupil who is studying general science, attempts to read textbooks on high school physics, chemistry, biology, physiology, and the like, wrong interpretations may result. The use of a scientifically prepared single textbook for the purpose of imparting basic understanding and minimum accomplishment in science subjects, with provisions for broadening and extended reference work for the brighter and more interested pupils, is considered by many to be more efficient as a method of teaching science. The extended amount of duplicated reading is eliminated for pupils who have less skill in the fundamental ability of reading.

Studies which have been made regarding the comparative efficiency of the Reference Method as compared with the Textbook Method show no significant difference in favor of one or the other.[2]

THE CONTRACT METHOD. This method consists chiefly in the preparation of contracts of work on two or more different levels which may vary in quality, quantity, or both. These levels are usually designated by terminology such as A, B, and C contracts; the A contract referring to the minimum or lowest amount of achievement, the B and C respectively requiring greater amounts of activity and study. This plan differs from the flexible assignment plan in that the pupil chooses at the beginning of the unit which contract he wishes to complete. This plan obviously helps to care for individual differences in ability and interest on the part of the pupils.

One disadvantage attached to this plan is that certain pupils tend to align themselves with a certain contract and continue to execute these same levels of contracts even though they have the ability to do the tasks required of more extensive amounts of work. Of course, a teacher can use his influence to encourage pupils to undertake the contracts for which their ability is commensurate. A second objection to the Contract Plan is the lack of flexibility usually attendant with a single contract. When the certain amount of

[2] Hurd, A. W.: The textbook versus worksheets in instruction, *Educ. Administration and Supervision, 17*: 661–664, 1931. Also in Curtis, F. D., "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 143.

work is done as outlined, provisions are generally made for additional and enriched experiences, and activity ceases upon completion of the prescribed activities.

The Flexible Assignment. This plan is similar to the Contract Plan in that it provides for different levels of activity, but instead of being compartmentalized into contracts, the form provides for a minimum essential amount of activity which the slowest pupils in the class should pursue in order satisfactorily to complete the unit. Additional activities, projects, and readings which pupils of greater interest, ability, and skill may choose to execute are provided.

This flexible assignment frequently may be organized on a two- or three-level basis, giving the pupils more definite goals for which to work. Most frequently, these levels can be designated as A, B, and C, with the A level including the simpler concepts and activities which should be successfully performed by the lowest third of the class. Level B may include additional readings and activities requiring more interest and ability, such as reproductive drawing, more extensive reading definitely prescribed, and the like. Assignment C includes activities of the creative type, such as preparation and organization of reports which may be given to the class, the performing and demonstrating of experiments, the construction of pieces of equipment, and creative drawing of the diagrammatic or artistic type.

This type of method tends to encourage the pupils to work to the level of their capacity and helps to keep the extremely low pupils up to a minimum standard. Guide sheets containing the unit theme, specific directions for study, study guide questions referring directly to material given in the textbook and reference books, additional suggestions for projects and reports, and enriched experiences such as field trips, are prepared and provided by the teacher or are prepared through the coöperative efforts of the pupils and the teacher. Commercially published guide sheets in the form of workbooks are available at the present time. It is the writer's opinion that such material prepared by specialists who have spent many years in testing these materials may be an improvement over the teacher-prepared materials. Great care should be exercised in the selection of such workbooks. When this is done,

much of the teacher's time and energy may be saved and more effective instruction in the subject may result.

THE PROJECT METHOD. The Project Method consists chiefly of building a comprehensive unit around an activity which may be carried on in the school room or outside. Some of the projects which may be carried on in the school room may be the hatching of chicks, around which an extensive unit on foods, heat, physiology, and other areas may be built; the construction and maintenance of an aquarium and a terrarium about which the biological and natural principles may be taught; the growing of plants in the seedbox, and the like. Projects which may be carried on outside the school room may be caring for certain domesticated animals, the growing and maintaining of a garden, a forest nursery including work in reforestation, and maintenance of homes for birds and bird feeders. Projects of this type serve as vital experiences around which fundamental science information and concepts may be learned.

A disadvantage in the exclusive use of this method is the difficulty in achieving efficient organization of instructional materials which will eliminate confusion and time-wasting on the part of the pupils. A second disadvantage is the difficulty and inconvenience resulting from the care and maintenance of these projects, especially care of domesticated animals and maintenance of a garden. It often ties down the teacher to the ultimate completion of the project as pupils frequently lose interest and neglect to fulfill their responsibilities as the unit is extended.

THE LABORATORY METHOD. The Laboratory Method has been found to be very effective in the teaching of the secondary school science subjects, especially in the areas of specialized science. It is psychologically sound because it satisfies the urge for activity which is a fundamental drive in human beings. The individual laboratory plan whereby every pupil participates in experimentation and firsthand experiences with materials and equipment is considered to be unjustifiable in elementary science because of increased costs. The method has been subjected to severe critical evaluation in the areas of the more advanced secondary school sciences. The results of research tend to show the following:[3]

[3] Noll, V. H.: "The Teaching of Science in Elementary and Secondary Schools," New York, Longmans, Green & Co., 1939, p. 47.

1. "Some time and money can be saved by lecture demonstrations over the Laboratory Plan, although just how much of a saving can be effected has never been carefully established.

2. "It has been shown clearly by a few investigations that individual laboratory work produces certain results in the pupil more efficiently and more permanently than does the demonstration.

3. "No careful student of the problem should or would advocate the discarding of either method on the basis of present evidence.

4. "Choice of which method to use depends on the total situation in which it is to be used."

General Conclusions on Methods of Teaching Science. There is no one best method, but the teacher should utilize the best portion of each of the methods which have been attempted and described and adapt these procedures to the problem at hand and to the personality of the teacher. The personality of the teacher is an important factor in determining the type of method which may be most effective. Teachers should try to study their problems in the light of the total situation and make adaptations accordingly.

More specific conclusions regarding the teaching of science may be given as follows:[4]

1. "Other things being equal, use lecture demonstrations for the more difficult and more expensive experiments.

2. "Other things being equal, use the individual laboratory experimentation method for simple, short, and less expensive experiments.

3. "Require pupils to prepare brief but carefully and accurately written reports of experiments.

4. "It is recommended that pupils make simple analytic drawings rather than representative ones.

5. "Use laboratory manuals when circumstances make it necessary or highly desirable, but not for all experiments.

6. "Whenever suitable, use workbooks as motivating influences and as stimulants to pupil activity.

7. "Use visual aids.

8. "Organize materials of instruction and present them by methods that encourage the pupil to a maximum of freedom and

[4] *Ibid.*, p. 47.

self-direction, and that permit the fullest possible provision for individual differences.''

STUDY QUESTIONS

1. What are some other methods of teaching?
2. Discuss the strong and weak points of the Lecture method. To what extent can it be profitably used in the secondary school?
3. Give a set of criteria for evaluating questioning.
4. What are the advantages and disadvantages of the Reference method? The Contract method? The Project method? The Laboratory method?
5. In what ways is the flexible assignment more suitable for the present-day needs in teaching?
6. What are the general conclusions about the methods of teaching?

ADDITIONAL PROBLEMS AND PROJECTS

1. Prepare a paper on how the different methods discussed in the chapter may be incorporated into the administration of the unit.

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UNIT FOUR

Specific Techniques in Teaching Science

In the previous unit an attempt was made to present a unified concept of the nature of the unit plan for teaching science subjects in the secondary school. In addition to the general plans for teaching there are several specific techniques which may be employed during the assimilation period. These must be discussed individually in detail. They are: (1) Directed or Supervised Study; (2) Conducting the Laboratory; (3) Demonstrations and Field Trips; and (4) Evaluation or Testing.

The directed study technique is a necessary part of the unit plan because of the individualized administration of the learning activities. Specific suggestions such as how to teach pupils to study, objectives of supervised study, principles to follow, length of period, and methods of checking the work of the pupils are presented for the reader's help. Many experienced and beginning teachers have an erroneous conception of what is expected of a teacher and pupils during such a period.

The science laboratory is a form of directed study and must be carefully planned and administered. There are numerous practical techniques in organizing and administering a laboratory which conserve the teachers' time and energy and at the same time increases the growth possibilities of the pupil. Participation of pupils in laboratory operation may serve to enrich the opportunities for worth-while learning experiences.

Demonstrations and field trips require a definite type of planning and procedure in order to acquire maximum value from their use. Pupil and teacher demonstrations possess advantages and disadvantages, depending upon proper implementation. The much advocated field trips present problems which require critical evaluation by all science teachers.

The outcome of science teaching is continuously being evaluated by pupils and teacher, but there are formal means, such as tests, which give a more objective result and meaning to estimates of pupil growth. Efficient evaluation necessitates great skill in preparing valid and reliable tests and tests which are readily scored and interpreted.

10

Directed Study

Under the Unit Plan of teaching, where the Assimilation period consumes at least three-fourths of the time devoted to the unit, it is obvious that a great deal of directed or supervised study is necessary. In actual practice, it is found that many teachers have erroneous ideas regarding the proper use of the directed study period. Many use it as a period for doing routine work, thereby leaving the pupils without adequate supervision. Under such management of the period the objectives are entirely lost. If properly conducted, the supervised study period keeps the teacher busy directing during each and every minute.

HELPING THE PUPIL TO HELP HIMSELF. The major principle in any form of directed study is to "help the pupil to help himself." Many teachers object to the Directed Study Plan because they claim that the pupils become too dependent on the teacher and are unable to continue study on their own initiative. This objection does not invalidate the plan of supervised study, but it does indict the manner in which the plan is used.

The plan of supervised study has several advantages over the nondirected study plan: (1) It provides supervision of study by the teacher of the subject which the pupil is studying. (2) It provides for immediate help in case the pupil is confused or has difficulty. (3) It reduces the amount of home work to a minimum. (4) It reduces the amount of extra school help which is necessary for slow pupils because they can be assisted right in the classroom during the supervised study period. (5) It reduces the number of failures.

The Supervised Study Plan of instruction has a few disadvantages. The most important is that it is more costly because it requires more teachers for its administration. The reason for this increase in cost is that no teacher supervises or cares for a study group larger than a regular class, while under the ordinary study

hall plan, a teacher may be in charge of a group of pupils numbering as many as 200 or more. It is evident that a teacher who has in charge a number this large can do little more than keep order; hence, no supervision of study is possible at all.

Principles to Follow. There are a few principles which the science teacher, or any teacher for that matter, should keep in mind in the conduct of a supervised study period. The first of these is that the teacher should constantly watch the progress of each pupil. A teacher should continue to circulate about the class to see how each pupil is getting along and help those pupils who ask for it. It is important to discover pupils who need help but do not ask for aid. They can be found by such continual observance of the work that is being done. After a few weeks of this constant observation, teachers can identify individuals who have difficulty and need more frequent attention.

Many teachers have the erroneous idea that a study period is a time when the teacher should sit at his desk and possibly do other routine work connected with teaching, such as checking papers. This is not directed study. A teacher who properly conducts a supervised study period rarely has time to sit at his desk because his services are needed constantly by the pupils of the class.

A second principle is to keep all pupils busy throughout the entire period if possible. This is generally achieved if the teacher constantly watches the progress of each child. In the majority of the cases, when a child quits working, it is because he is having difficulty. If these difficulties can be overcome immediately, the child tends to continue with the task at hand with interest and enthusiasm which carry him through to the end of the period. Constant encouragement on the part of the teacher aids greatly in continuing the pupil's effort. The teacher should be ready to compliment the child on his achievement so that he may be encouraged to do more and better work.

It is impossible, of course, to keep all children working for an indefinite period because we know that a concentration period, especially of junior high school pupils, is rarely more than 40 minutes. Knowing this fact, the teacher can guard against wasteful periods. If a large number of the pupils indicate the desire for change, the wise procedure is to close the study period and begin

a discussion. This tends to avoid a period during which a great deal of time is wasted. Often, it is possible to have a discussion period involving only a few pupils, permitting those who want to continue with their individual work to do so.

Techniques of Checking Work. With the use of study sheets, it is practically necessary that pupils be required to write their results on paper because it is impossible to check a child's achievement or study habit unless some objective means is used. Pupils may sit and look at a book and still not be reading at all, although they appear to be accomplishing something. If a record of this accomplishment is made on a paper, that is, if answers to questions are written down, even in a brief form, it is possible for the teacher to estimate more accurately the progress of the child. This necessity for constant checking of a child makes it mandatory that the teacher move about the class as was suggested above.

In order to avoid the burden of numerous notebooks and papers at the end of each unit, it is obligatory that the teacher constantly evaluate the child's work, not necessarily by putting a grade on the paper but by observing the work so that the teacher has well in mind its quality with regard to each pupil at all times. It is generally found helpful to grade the pupil's work as soon as the minimum essentials have been completed. This may be done by putting a grade on the pupil's paper and recording his grade in the class book. It is found that by the time the unit is closed, from one-half to two-thirds of the pupils will have had their work checked. Supplementary and additional materials may also be checked during this Assimilation period. The remainder of the notebooks or papers may be checked while the pupils are taking the mastery test. If this procedure is followed, it is rarely necessary for the teacher to have any notebooks or any papers to check after the unit is closed, except for pupils who have been ill or absent. This final checking during the time when the pupils are taking the mastery examination can be done very quickly because the constant checking on the part of the teacher enables him to know in general what kind of work the child has done; hence, the accuracy of each item need not be checked. If the teacher has been unable to get an evaluation of the child's work by the routine checking during the Assimilation period, it may be found helpful to single out certain key items

which are more likely to be inaccurately solved, and to check them.

This continual checking reduces almost to nil failure of pupils, and improves the quality of the work of all because it utilizes the psychological principle of "Readiness" in the correction of errors and helps in future work.

LENGTH OF SUPERVISED STUDY PERIOD. The length of the directed study period can be approximately twice as long as the discussion period, depending upon the age of the pupils. It is found that a directed study period of from 30 to 40 minutes is generally successful in a junior high school, and gradually increases to 50 minutes or an hour for pupils in the senior high school. The length of the period, of course, is not arbitrary but is dependent upon the day of the week, weather, conditions of the room, the interest exhibited in the material of the unit, and the like. A sound technique to follow is to change the procedure if the procedure at hand does not seem to keep the pupils working. It is better for the teacher to be resourceful in the procedure employed than to exert external pressure in the form of disciplinary measures, as these are only temporary in effect and cause antagonistic attitudes on the part of the pupils toward the subject and the teacher.

It is wise for the teacher not to plan too many continuous periods of entirely supervised study without the injection of stimulating discussions and demonstrations. It is desirable to have pupils work individually according to their own rate for a considerable length of time, though for many individuals in any class this becomes tiresome and without purpose. Hence, stimulation by means of a change and demonstrations as previously mentioned is necessary to keep up the efficiency of the whole class.

TEACHING PUPILS HOW TO STUDY. Even with the aid of detailed study guides it is necessary for the teacher to help the pupils to use the study guide effectively. Without such direction on the part of the teacher, pupils tend to revert to slovenly and inefficient methods in carrying out the suggested activities and answering of questions provided on the guide sheet. It is found that the same procedure does not apply equally well to all pupils. Differentiation seems to be based upon factors such as intelligence, reading ability, and personal characteristics such as persistence, resourcefulness, physical vitality, interest, and attitude.

Frequently, a considerable length of time is required to train pupils to study effectively under the teacher's supervision, especially if they have not been accustomed to the procedure. With a majority of classes, continuous effort for an entire semester is necessary for satisfactory utilization of the supervised study period by all the pupils in a class. In a normal class it is found that a few of the slower pupils are incapable of acquiring what may be considered effective study techniques. In spite of this pessimistic picture with reference to the lack of ability on the part of a few slow pupils, which are found in any average class, to master efficient methods of study, directed study greatly increases the efficiency of teaching.

It has been found effective to urge pupils to give several methods of study a trial in order to determine for themselves which technique they like best and which one is most effective. Pupils who are new to this method of directed study with study guides profit a great deal from a coöperative discussion and experimentation with several approaches. Some pupils can reason out for themselves which method is most effective and employ it consistently from the beginning without giving the others a trial.

Three different approaches can generally be drawn from the pupils by a clever teacher. If this cannot be done, the teacher may suggest them. The first and generally most successful method of study for pupils in all secondary school grades is for the pupil to read the entire chapter in the text and then attempt to answer the questions on the study guide or in the book wherever they may be. It is helpful to glance through the questions before reading the material, thereby using them as a guide in the reading. The pupil generally is able to answer a majority of the questions without referring to the material. The answers of which he is uncertain can be found readily in the skimming or rapid rereading process. The answers can be found quickly because the pupil knows where to look for them as he is familiar with the material.

A second method of study is to read a few paragraphs at the time and then go back to answer the questions pertaining to this relatively small portion of the chapter. After these questions have been answered a second portion may be read and the process repeated until the entire chapter is mastered or at least finished. This

piecemeal method seems to work better for pupils of lower mental and reading ability.

A third plan is to read the question first and then hunt for the answer. If the study techniques are not closely watched, too many pupils tend to revert to this approach, especially those who lack interest and are of lower ability. In order to avoid this wasteful procedure on the part of lethargic pupils the teacher should follow up the stress on efficient methods of studying with the class as a whole and with individual pupils. Class discussions on the problem, including testimonials by the pupils as to their experience with the different methods of study and their reasons why and how they save time and energy by using the more efficient techniques are helpful. It is better to have the pupils find out for themselves and decide for themselves which approach works best for them and which one they prefer to use. If certain pupils persist in using poor methods after reasonable effort on the part of the teacher to remedy the tendency, it is better to let them do it their own way than to antagonize and develop a negative attitude which may decrease rather than increase their growth in the area studied.

Pupils should be handled as individuals and different approaches must be permitted with certain ones. It is preferable, in general, to have pupils follow the sequence of activities outlined on the study guide. It is found that a large majority of the pupils prefer to follow this plan. Nevertheless, a few pupils rebel against this procedure and as a result accomplish very little during the study period. It often helps to let such pupils browse around the bulletin board, play with equipment, watch the aquarium, or engage in other activities which do not materially disturb the rest of the class. After a while they become interested and proceed with their tasks of their own accord. If possible, the teacher should attempt to reach each and every pupil through his interests, but if the teacher's resources are exhausted, the only alternative is to compel the pupil to get a minimum number of questions answered or do a minimum amount of work. Frequently, if they are made to do something, they begin to like it.

Most frequently when a pupil is doing nothing, and sits and dreams or gets into mischief, it is because he is having difficulty with the task at hand. In such a case the teacher should help him

over the "hurdle," even to doing the task for him. Pupils are motivated by success. The old adage, "Nothing succeeds like success," is an excellent guide to keep in mind while teaching both children and adults. Pupils do not like to stand still; they want to make progress. Therefore, an occasional "outright aid" from the teacher tends to make them more self-reliant and enthusiastic rather than less independent.

Occasionally, certain pupils prefer to study other subjects during the directed study period of a certain subject, for instance, science. In most instances the pupil has done as much on a certain unit in science as he cares to and generally has gone far beyond the minimum requirement. In such cases it is justifiable to permit the pupil to follow his wishes. There is very little danger that other pupils will want to follow suit. Should too many pupils want to study algebra, for instance, instead of science, it would be time to call a halt and require all of the pupils in the class to pursue the study of science during the directed study period. Such a degeneration of the study period often is due to undue pressure of the other subjects, or to a lack of challenge on the part of the science experiences. It is the duty of the science teacher to make the diagnosis and devise means of correction.

Some very capable pupils may be excused from following the study guide should they so desire and if they can pursue their own plan without disturbing the other pupils in the class. The degree of growth can be checked by performance of this special pupil on the unit examinations. If the achievement of the pupil is reduced significantly, it may be wise to convince him that it may be more satisfying to follow the study guide. The writer once had a girl in a class in senior chemistry who felt that the study guide required too much time and she asked for permission to spend the directed study period in working on the school paper of which she was editor. This request was granted and she was able to maintain her previous level of achievement.

STUDY QUESTIONS

1. What is the interpretation of "directed study"?
2. Describe some erroneous uses of the supervised study period.
3. In what ways is the directed study plan superior to the nondirected study plan of teaching?

4. Name some of the principles that should be followed in directing the study of pupils.
5. Describe the procedure in checking the progress of pupils during the supervised study period.
6. Discuss the factors which determine the length of the supervised study period.
7. Outline a plan for teaching pupils how to study.
8. Under what conditions is it advisable to permit pupils to pursue their own methods of study?

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11

Conducting the Laboratory

A laboratory in science is a form of supervised study and therefore it is guided by the same principles as those which were discussed under the heading of "Supervised Study" in a previous chapter. In science, a laboratory period generally means that pupils perform some experiment or some activity with the help of a well-prepared guide which we usually call the "Laboratory Manual." This generally affords considerable freedom and physical activity which tends to permit a longer period because of the nature of the activity.

PRINCIPLES IN THE ADMINISTRATION OF THE LABORATORY

The laboratory in any science subject should be thoroughly and skillfully organized. Otherwise, a great deal of waste may result. In the first place, the laboratory period should be perfectly correlated with the class work. For example, when the class is studying sulfur, the experiments with sulfur should be utilized in the laboratory. If any unit is studied which provides for no laboratory experiments, no experiments should be done. In order to secure the greatest benefit from the activities in the laboratory, it is absolutely essential that pupils be prepared with an adequate background, which is achieved through class discussion and study. Pupils should be thoroughly familiar with the purpose of the experiment and the principles which they are to discover through this activity.

It is not enough to give the pupils a manual and let them go to work in a laboratory without any further direction and discussion. Every laboratory period should begin with a discussion of the experiment to be performed. Cautions and recommendations as to procedure should be clearly and thoroughly given. These helps which can be suggested by the teacher can save pupils, especially the slower ones, a great deal of time and energy, thereby determin-

ing whether or not their activities in the laboratory will be successful. The pupils should be cautioned against the many hazards encountered in the laboratory regarding the possibilities of personal injury and injury to equipment. In the area of personal injury, cautions in the handling of glass tubing, hot materials, and acids, especially in the chemistry laboratory, are necessary to reduce accidents to a minimum. Accidents in the laboratory are absolutely unnecessary. It has been the writer's experience that they can be entirely avoided if proper procedures are used. Cautions and thorough directions are necessary. Above all, absolute order and freedom from confusion contribute to the greatest extent to the safety of the pupils.

The teacher should be constantly watching the progress of each and every child in the laboratory. It is helpful for the teacher to assume a position in the laboratory from which every pupil can be observed. The teacher should be in the laboratory at all times and not in some other room, in a supply room, or at his desk doing some other type of work. If such a favorable vantage point is taken, it is possible to move from that point to any pupil who appears to need assistance, and as soon as that child is given the suitable help, the teacher should immediately go back to this vantage point to be ready for further help.

Assistants Should be Used. If the teacher is to assume this position of watchful observation, it is mandatory that pupil assistants be employed to care for the routine activities of the laboratory. Such assistants may be chosen according to several criteria: (1) An assistant may be chosen because of his interest in a subject. (2) Problem cases often may be assigned laboratory duties because generally the reason why a child is a problem case is that he has no responsibility and has very little interest. An assignment of laboratory responsibility may stimulate his interest in the subject and hence correct the tendency toward noncoöperation. (3) The efficiency of a pupil. Many pupils can do a great deal of extra work without impairing the execution of their regular tasks.

Duties which can be assigned to such assistants are many. Assistants may be assigned to help pupils with moderate difficulties such as opening the locks, setting up of simple equipment and apparatus, remedying difficulties in pieces of equipment, and the

like. An assistant may be given the responsibility of finding supplies and equipment in case pupils want them. A pupil can become familiar with the supply room and equipment room in a very short time, and when a pupil wants a certain piece of equipment or supplies, the pupil may be referred to the assistant who can satisfy his need. This permits the teacher to remain in the laboratory in supervision of the experimenters. It is often helpful to have the boy who is responsible for the supplies come to school early in the morning or before school begins for the purpose of assembling the materials and equipment necessary for the experiments of the day. This will give the teacher more time to prepare a discussion or instructional materials which can make the unit or experiment more interesting and successful.

Assignments may be made in the different areas of keeping the laboratory in proper condition. Certain pupils may be assigned to keep the drains clean in the chemistry laboratory, to see that all equipment is put back in the proper place, to see that the windows and curtains are properly adjusted at the end of the period, and other details, even to the extent of recording write-ups of experiments which the pupils occasionally are requested to do.

LABORATORY PLANS

There are two general plans in the administration of a laboratory: (1) The Group Plan, and (2) The Individual Plan.

THE GROUP PLAN. The primary characteristic of the Group Plan of laboratory administration is that all pupils perform the same experiment at the same time. This plan has the main advantage of ease of administration. Under this plan, the provision for equipment and supplies is greatly simplified. Equipment and supplies for this certain experiment or experiments can be placed ahead of time where pupils can readily serve themselves, thereby preventing a great deal of confusion at the beginning of the period. The same directions can be given to the whole class, thereby avoiding the almost unsurmountable difficulty of giving numerous different directions. Group help can be given. Should a teacher observe certain errors in the conduct of an experiment by several pupils, the remedial directions can be given to the whole group in the minimum amount of time.

According to this plan, individual differences can be efficiently cared for by providing for additional experiments which bright pupils may perform should they care to do so. Nearly every laboratory manual, either in physics, chemistry, or biology, contains at least twice as many experiments as the average class finds time to do; therefore, the supplementary experiments are plentiful. For classes of more than 20 pupils, the Group Plan is recommended.

The Individual Plan. Under the Individual Plan of conducting a laboratory, each pupil or group of pupils performs the experiments as fast as they are able; hence, after a short time, each group is doing a different experiment. This plan apparently cares for individual differences in a more efficient manner than the Group Plan, but difficulty of administration makes it rather impractical, especially in large classes. Under this plan it is practically imperative to have a full-time person dispensing chemicals and equipment, and in the average high school such a dispenser is not provided. Generally it results in considerable confusion and difficulty in the securing of supplies and equipment on the part of the pupils because of a great deal of waiting and wasted time and frequently delayed aid on the part of the instructor. It tends to foster non-correlation with the class work because pupils are not kept together and, as a result, experiments on many different units are performed in the laboratory while a certain unit is being discussed in the classroom.

Organizing the Laboratory. The classes should be organized for laboratory study as soon as possible after classes begin for the semester or year, preferably during the first week. It is important to have pupils work with their friends or fellow pupils whom they prefer in order to maintain a normal social situation. Pupils are happier and do better work if they are given a free choice in this matter. The teacher should suggest that each pupil take a seat at a laboratory desk with the pupil with whom he would like to do his laboratory work. The teacher will find that very few changes in seating will be necessary, because, if freedom with respect to seating is permitted, pupils will have chosen seats by their friends upon entering the laboratory on the first day. This pattern of seating will take place in the recitation room, also.

When the pupils have arranged themselves according to choice, they are ready for the assignment of laboratory desks and equip-

ment for which they should be held responsible. After the desks have been assigned, cards measuring 4 x 6 inches may be passed to the pupils upon which they are asked to give the following information: (1) full name, last name first; (2) name of laboratory partner; (3) locker or desk number; (4) book and manual number; (5) address; and (6) telephone number. Information as to the address and telephone number can save the teacher a great deal of time in locating the pupil without going to the office records. These cards may then be arranged alphabetically and filed for quick reference. Space may be provided on this card for the recording of additional equipment which is checked out from time to time because of breakage and need.

In the chemistry and biological laboratory, pupils would be given a certain standard set of equipment for which they should be held accountable. At the end of the semester, each group should be required to return, in good condition, these pieces of equipment or their equivalent in money. A convenient way which has been found to check out this equipment is to have pupil assistants aid in placing the standard equipment in a pneumatic trough. One member of each group may come to the supply room, and the members of the group are held responsible for checking the equipment with a standard list which is placed on the blackboard, and for seeing that each piece of equipment is received in good order. At the close of the course, this equipment is returned in these troughs after careful cleaning, and pupil assistants may be employed to check in the contents and place the equipment in the proper shelves in the storeroom.

In the physics laboratory, very little, if any, equipment needs to be checked out to groups because the average laboratory has enough equipment to permit this procedure. Physics equipment is too expensive for the justification of individual or group equipment. Rarely more than a few duplications are justifiable or can be afforded. Therefore, apparatus must be rotated among from four to eight groups, depending upon how many experiments can profitably be performed during a single unit. The equipment used must be checked out at the beginning and in at the end of the period. A chairman of each group may be appointed by the teacher or elected by the group who will be responsible for the accounting of the equipment. A pupil assistant may help the instructor to see

that no equipment is lost and to see that it is placed in the proper place in the cabinet.

TECHNIQUE IN RECORDING EXPERIMENTS

There is considerable difference of opinion as to the value of write-ups by pupils of experiments after these have been performed. Studies show that very little value is derived from this procedure. It tends to become a burden for the pupils and the teacher. Nevertheless, it has been the writer's experience that more careful experimentation is done if some sort of check is made on the quality and understanding of the experiments performed. In view of this, it is apparent that some method of recording the experiment might be desirable, though the burden of doing so should be reduced to a minimum. Under this plan, it might be advisable to have mimeographed forms on which the pupils can record briefly the results and conclusions of the experiment. This report should not include more than one page. A practical report may include the following phases:

(1) Problem or purpose
(2) Procedure
(3) Results
(4) Conclusion

The pupils should be encouraged to make these recordings during a laboratory period when the experiment is being performed. When the experiment is completed, the pupils may make their recordings immediately, and subsequently may bring it to the instructor for evaluation. The instructor may, then, at a glance, see the results and conclusion and decide whether it is satisfactory or not satisfactory. A notation of *satisfactory* may then be made on the sheet if it is acceptable; if it is not acceptable, the correction may be suggested and the pupil may make the correction promptly and return the sheet for approval. This sheet may then be retained by the instructor, or given back to the pupil who may be requested to place it on a certain shelf in the laboratory. These papers may be picked up later by the instructor or preferably by a student assistant whose responsibility it is to make a record of these approved summaries.

Under this plan, it is found that the recording of experiments is a burden neither to the pupil nor to the instructor. Generally, a

large majority of the pupils get the write-up of the experiment approved before the end of the period, and the instructor has no experiments to check outside of class period. It avoids the monthly checking of stacks of notebooks which represent an undue burden on the teacher. It is found, under this plan, that practically all the pupils have all experiments written up. It reduces copying to the minimum, and does the same in the area of failures.

DRAWING AS AN AID TO LEARNING

The place of drawing in science study has been achieved largely through traditional practice without a critical and experimental evaluation as to its efficiency as a teaching procedure. The function of illustrations, charts, and maps is to aid the pupil in the understanding of scientific principles and facts. It is accepted that these aids frequently are more effective than words in achieving clear mental images and correct understandings. The fallacy associated with the practice of utilizing the drawing procedure in teaching is that it is of uniform efficiency as a learning activity for all pupils. Also, there is a difference in the desirability of type of drawing employed. It is evident, then, that the science teacher should know how to use the drawing procedure most effectively and what types of drawings have been found through experience and experimentation to be functional in teaching science subjects.

Frequently, drawings become an end in themselves and the principles and understandings are lost in the activity. For example, a chemistry teacher required every pupil in his class to make a large, inked drawing of the device used to manufacture sodium. Pupils spent many hours on this project. It is far better to make projects of this sort optional for the pupils who get satisfaction from the activity than to require it for every pupil in the class. Pupils differ greatly in their skill in making drawings whether they be the representative, diagrammatic, or artistic type. It is very improbable that very much learning takes place when a child is forced to make a drawing which he cannot do with reasonable skill.

Principles in Employing the Drawing Technique. The principles presented in this paragraph refer to drawing as a pupil activity. Drawing as a teacher activity may be very helpful in teaching pupils. Teachers who have developed the ability to draw

or sketch should by all means utilize this art to its fullest extent. The teacher should remember that because he is skilled in drawing and because he learned a great deal from drawing activities in studying college or high school science, this does not mean that all his pupils will benefit equally from the activity.

The first principle is that, in general, pupils should be permitted to decide for themselves, individually, whether or not they want to draw. This makes this activity optional and may be placed on the enrichment level of the assignment. The degree of elaborateness of the drawing, whether it should be inked or colored, should be left to the pupil's own choice. Pupils with special talent in this area should be encouraged to do more of it in the science courses and to take other courses given in the school in the area of drawing or art. This principle holds true as well for the reporting of laboratory experiments.

The second principle is that drawings should be diagrammatic rather than representative. Experimental studies in the field show that representative drawings are of little value.[1] Drawings should be accompanied with detailed explanations as to their interpretation. Diagrams tend to bring out more clearly the scientific aspects which need emphasis. Labelling of prepared sketches is found to be a great time-saver and is considered to be more efficient. Whenever this activity is considered important enough to be required of all pupils in a class, the already prepared sketch should be employed. In case of drawings which are considered too complicated for a majority of the pupils, the prepared sketch may be used for the purpose of pupil-labelling and interpretation.

NOTEBOOKS, MANUALS, AND WORKBOOKS

At the present time there is considerable controversy regarding the use of notebooks, manuals, and workbooks. Should pupils be required to keep a notebook in all or any one of the secondary school sciences? What type of laboratory guide is found to produce the best results with the average secondary science class? Do workbooks increase the efficiency of science teaching? These are some of

[1] Bellew, A. M.: *School Review, 36*: 284–295, 1928. Also in Curtis, "Second Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1932, p. 195.

the issues which the science teacher must study critically with a view to finding at least a tentative answer.

We must consider first our basic philosophy of education. A sound principle in educational psychology and philosophy is that pupils learn by doing and that therefore the primary objective in determining a technique of instruction is to provide for a maximum of pupil activity. This pupil activity must be efficiently directed in order that the objectives of education may be achieved to the greatest possible degree. In this day of mass education, it is necessary to make use of the best already prepared devices for providing worth-while learning experiences for pupils because the average teacher has neither the time nor the ability to prepare adequate teaching materials.

Notebooks. Critical thinking on the matter of compulsory notebooks in science subjects seems to indict the practice as lacking in usefulness. It is no longer necessary for graduates of the secondary schools to present notebooks to the large majority of colleges or universities as evidence of the quality of work done in the sciences and the quality of science instruction received. Less than 25 per cent of our high school graduates go on to college where such notebooks may be required for entrance. In the light of the two preceding facts it seems reasonable to adopt a policy of making the keeping of notebooks in any secondary school subject a matter of individual choice by the pupil. Pupils who prefer to keep a comprehensive notebook and who get satisfaction from doing so should be encouraged in the task. If keeping notebooks is for the purpose of future reference for informational purposes, it may be better for the pupil to purchase a textbook which will have this information in far better form. The high school graduate who refers to his high school notebooks during later years is a rare specimen.

This conclusion does not mean that the pupil should not write up or make a record of his experimental findings. Such records are made for the teacher to check to see if the pupil has learned the principle involved. A teacher can check such brief reports more quickly than he can check each pupil orally. It is impracticable to require pupils to file these reports in a notebook unless they prefer to do so. Experience indicates that these records of secondary school experiments are rarely again referred to by the pupils.

Laboratory Manuals. There is considerable variance in the opinions of teachers in the field and experts in the teaching of science regarding the use of laboratory manuals. This controversy appears to be primarily as to whether prepared manuals should be used at all; whether they should be prepared for a single textbook; or whether they should be applicable to several texts or be independent from organized subject matter.

After critical study of the controversy it seems most practical to employ a commercial manual prepared for a single textbook. Justification for the use of a prepared manual lies in its advantages, the most important being that the average teacher-prepared laboratory guide is certain to be inferior. The average teacher has neither the time nor the ability to prepare an efficient guide that can compete with one that is a result of many years of teaching in the field, coupled with a backing of sound educational philosophy and psychology.[2] This policy does not mean that all commercially prepared manuals are adequate. It means that the teacher must take great care in selecting the textbook and manual which fulfill the objectives desired. In other words, the crux is in the selection of the instructional materials. The average science teacher in the public schools will do well to have the ability and time to select these materials, let alone prepare them.

The manual should be prepared for a single textbook because it provides for a more closely correlated or integrated course. Present texts in science on the secondary school level are prepared systematically enough to provide a certain amount of progress in difficulty and development. Few textbooks are uniform in this respect. This difference is great enough to contribute to confusion in the understanding of scientific principles developed in the respective units. For instance, one text presupposes understanding of the principles of heat before taking up the unit on weather, or a book in chemistry presupposes the knowledge of valance before presenting the unit on water. It is evident that much confusion and unnecessary duplication in reading attends the use of several different texts, even in general science. Proponents of the multiple textbook plan stress the breadth of outlook which is an important objective in science teaching. In answer to this it may be said that

[2] See p. 66 for discussion on textbooks.

the modern single textbook provides for enriched material for those who are able to assimilate it. The slower pupils have difficulty in assimilating one point of view without being confused by controversies or many plans of presentation.

New texts and manuals should be secured at intervals of five years in order to keep up to date in content, organization, and method of teaching. Prepared materials may be supplemented by teacher-prepared materials if the teacher chooses.

WORKBOOKS. Workbooks may be an effective teaching device providing the proper workbook is procured and the proper methods are employed in its use. The principal current objection to workbooks has been the improper use of them. The purpose of workbooks is to guide the individual activities of the pupils so that individual differences may be adequately cared for in large groups. Actually, a good workbook is no more than a series of study guides bound together in book form. Some of them are loose-leaf and some are securely bound. Generally, they are a result of several years of experimentation with study sheets which have been improved in the light of experience with them in a science classroom.

There are many textbooks on the market which include self test questions and suggestions for further reading, and projects for each problem and unit. These texts may be used without the use of workbooks or teacher-prepared study guides. Nearly all textbooks published today either have the study guides in the book itself, or an accompanying workbook is available. These published guides are far superior to those prepared by the teacher. The teacher, then, should secure these helps and spend his time supplementing the prepared materials. When this procedure is followed, maximum efficiency in teaching can be achieved.

Studies disagree on the results of evaluating the relative merits of study guides or workbooks. Two studies, however, tend to find advantage in the prepared materials. A. W. Hurd[3] found the use of study guides superior to the conventional recitation plan in securing desirable results; and Peterson and Douglass[4] concluded

[3] *School Review, 39*: 608, 1931; *Educ. Administration and Supervision, 17*: 661–664, 1931; summarized in Curtis, F. D.: "Third Digest of Investigations in the Teaching of Science," Philadelphia, The Blakiston Company, 1939, p. 143.

that the relative efficiency of the workbook and the pupil-made notebook depends upon the teacher. The latter study further indicated that workbooks achieved better results with brighter pupils and notebooks were a superior learning activity for slow pupils.

STUDY QUESTIONS

1. Why can laboratory work be considered as a type of supervised study?
2. Give the characteristics of a well-administered laboratory period.
3. In what ways may pupil assistants be effectively used?
4. Compare the Individual Plan and Group Plan with relation to efficiency in teaching secondary school science.
5. Outline a procedure in organizing pupils for laboratory work.
6. Describe the procedure in checking and recording write-ups of experiments.
7. What are the conclusions in regard to drawing as an aid to learning?
8. Should notebooks be required of all pupils? Why?
9. What are the conclusions with respect to the use of commercially prepared laboratory manuals versus teacher-prepared laboratory guides?
10. What are the conclusions regarding the use of workbooks?

ADDITIONAL PROBLEMS AND PROJECTS

1. Write a critical evaluation of at least three laboratory manuals.
2. Evaluate at least three workbooks with respect to their efficiency as an aid to improved teaching.

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12

Demonstrations and Field Trips

Demonstrations and field trips are effective in making science subjects more real and interesting to pupils of all grades. The value of the demonstration as a teaching device has been subjected to scientific investigation for many years, especially with relation to the efficiency of the individual laboratory plan of teaching science subjects. The effectiveness of field trips has been estimated on the basis of opinion, casual observation, and critical analysis rather than by means of controlled experimentation.

DEMONSTRATIONS

Demonstrations are very effective in motivating the study of all science subjects. Pupils like to see actual demonstrations and actual operation of different pieces of scientific equipment which illustrate certain principles. Demonstrations serve as a point upon which to concentrate attention in a discussion. It is difficult to talk about things which pupils have to imagine. It is far better to have a concrete object, facsimile, or model of the problem under discussion.

DEMONSTRATIONS MAY EFFECTIVELY DISPLACE LABORATORY WORK. In many school systems, especially those enrolling a small number of pupils, the Demonstration Plan is being employed instead of the laboratory. The primary reason for this substitution is the cost of laboratory equipment. Studies which have been made relative to the efficiency of the Demonstration system versus the Laboratory method of teaching all science subjects revealed that the Laboratory Plan effects greater retention than does the Demonstration Plan. However, the increased amount of retention achieved by the Laboratory Plan is not very great, and many authorities question whether the additional expenditure of equipment and time warrants the use of this more costly plan.

According to the principles of the more modern psychologies, the Laboratory Plan provides for a definite need. The modern

trend is toward increased activity and actual first-hand experience for pupils in all areas of study. The laboratory, then, provides increased activity for the learner. "Learning by Doing" is a maxim of modern education and also follows an important principle in the psychology of learning.

Pupil or Teacher Demonstrations. Demonstrations may be performed by either the pupils or the teacher. Many factors may enter into making a decision as to who should perform a certain demonstration. Generally, the teacher should perform those of too great a difficulty for effective and safe performance by pupils. During teacher demonstrations, however, pupil assistants may be appointed to help in many ways. Pupil assistants tend to stimulate interest on the part of the other members of the class, and it also gives valuable experience for those in active help.

Demonstrations which can be easily seen by the whole class from where they are regularly seated may be successfully performed at the teacher's desk. It is seldom desirable and effective to have pupils crowd around the desk, especially when the classes are large. Where pupils crowd around the desk, many of them fail to see the demonstration because of insufficient room, and not only lose the benefits of the demonstration, but often get into mischief because of this, thereby creating a disciplinary problem. This type of demonstration may be effectively carried out by a different method which will be described in the succeeding paragraph.

Pupil demonstrations may be performed by a single pupil or by a committee of two or three pupils. These demonstrations must be well prepared by the pupil. Generally, a pupil may choose the demonstration which he desires to perform, and make careful preparation for it. After the pupil makes known that he is ready to make a demonstration, the teacher should check to see that it is properly prepared. After this preparation has been deemed satisfactory, the pupil may then bring this demonstration around to the rest of the pupils of the class during the supervised study period. If the pupils are seated at tables, the demonstration may be performed for all the pupils at that table. This plan provides for close observation and participation on the part of the observing pupils in handling of the equipment or materials which are being demonstrated. The individual pupil demonstrator or the commit-

tee which demonstrates will perform at the successive tables until all the pupils have been reached.

It is possible to have from one to four of these demonstrations operating during the same period, but it has been found that less confusion results if the number of demonstrators are limited to one and two during a single period. Frequently, it is necessary to have as many as four or five demonstrations in order to give each pupil or group of pupils a chance to demonstrate. Pupil demonstrations by individuals or committees in this manner gives an opportunity for activity on the part of many individuals who benefit greatly thereby. It provides for experience in manipulation of equipment, handling of materials, and practice in expression while making these demonstrations. Socialized activities are provided for while these pupils are contacting the different groups at the tables in the room.

If pupils are arranged in rows of individual seats instead of at tables, the class may be divided into small groups which may assemble about a single pupil's desk where the demonstration is performed. The assembling of such a small group eliminates all objections to the ordinary class crowding about a desk because every opportunity is afforded for a complete view and for asking questions during the demonstration.

A Demonstration Must Be Well Planned. It is rarely possible for the average teacher to perform a successful demonstration without thorough preliminary planning. Beginning teachers who have not performed these demonstrations several times before should always try out the demonstration before class time. Unless this is done, it too often happens that it is a failure. All materials and equipment should be on hand so that it will be unnecessary for the teacher to leave the room to secure such materials or to send a pupil out to get them. It occasionally happens that, even with thorough planning, some pieces of equipment or material fail to be brought to the desk. Occasional errors of this type are permissible but certainly should not be common.

If a demonstration fails, it has a definite undesirable effect upon the morale and attitude of the class. If failure is too frequent, confidence of the pupils in the teacher is lost, and disciplinary problems often result. Inadequate planning, also, has the same

effect. If it is necessary for the teacher to leave the room to secure equipment and materials, the class becomes disorganized, causing the possibility of a disciplinary problem and generally of a disorganized and turbulent atmosphere. Usually, it is better to omit the demonstration and perform it at some other time than to attempt to prepare it during class time.

FIELD TRIPS

The field trip is an effective technique for teaching if handled skillfully. Plans for these activities must be thorough and definite in order to avoid confusion and waste of time. Generally, a field trip should be correlated with the unit of study, and a thorough background for this experience should be prepared before the event takes place. It is helpful to prepare, with the help of the class, a list of questions or items which should be observed. After the field trip has been completed, a comprehensive discussion should be held in order to fix and unify the experiences which the pupils have had. If possible, the discussion may be conducted during the tour or immediately afterward on the premises.

Definite plans must be made in order to insure safe transportation of the pupils to and from school. This is the responsibility of the teacher, and entails many hazards. The most desirable means of transportation are chartered public carrier buses. Many school systems own their own buses, and under such circumstances these should be used. Often, the cost of the hiring of public carriers is prohibitive, and under such circumstances it might be better to give up the field trip than to utilize other more hazardous means of transportation.

If the distance is not too great, a desirable means of getting to the place of observation is to walk. Cars driven by pupils entail so much hazard that it is wise not to permit this at all. It may be satisfactory for parents to do the driving if private cars are necessary for transportation. The teacher should see that such automobiles are in proper condition, and have proper insurance to cover any accidents which might happen. The teacher should also investigate the parents' driving ability. The main responsibility is to care for the life of the child and good judgment should play a part in the handling of this phase of the field trip.

Disadvantages of Field Trips. The use of field trips in the public schools as now organized involves many disadvantages which are practically impossible to overcome. These limitations may be listed as follows:

1. *The school program is disrupted.* The average secondary school employs periods which are from 40 to 60 minutes in length; and because of the inadequacy of this time for a complete trip, the periods following are generally intruded upon.
2. *The hazard of taking a class comprising 30 to 50 pupils is very great and this difficulty increases as age of the pupils decreases.* Possibilities of accidents, both on the street and in the factory or establishment visited, are very great. Even under good supervision, buses have been hit by trains, killing scores of innocent children.
3. *A very small portion of such a visiting group gets the full significance of the activity.* In the majority of cases, the guides are untrained, tending to speak to only those persons who are fortunate enough to be able to get close to them. Often, the object under discussion is hidden from the view of a large portion of the pupils because of crowding and lack of room; hence, they miss out on both the visual and auditory end of the supposed learning experience.
4. *The rental of buses or the purchasing of the transportation equipment involves a great deal of expense to the public.* In the average city of 40,000 population, the rental fee for a 40-passenger bus is $7.50 per hour. Transportation in private cars with pupil drivers is a distinct hazard which should be strongly discouraged if not prohibited.
5. *Many establishments are not equipped for handling large groups such as the average class.* This means that the classes must be broken up into two, three, or four groups with many inferior guides and without teacher supervision.
6. *Many establishments propagandize rather than educate.* Generally, the establishments bring out sales stimulation propaganda, thereby using this opportunity for advertising their product. In many cases, the vital information is overshadowed by the sales talks.
7. *The trips cannot always be arranged at the psychological time during a unit.* The establishments often find it inconvenient to permit a tour because of excessive production, unavailability of the guides, and the like.

It may be that, in many instances, sound moving pictures can be effectively substituted for field trips, thereby eliminating many of these disadvantages.

Required Field Trips. Field trips may be of the required type or may be voluntary in nature. The required type generally are planned for the whole class and most frequently conducted during

the regular class period or during school time. These trips must be carefully planned so as to derive the maximum value from them. It is well to prepare the class by means of reading and discussion from which a comprehensive set of questions and things to look for may emerge. This list of guiding items should be mimeographed and placed in the hands of every pupil at the beginning of the trip. Such planning necessitates that the teacher make a preliminary survey of the area, factory, or establishment to be visited. Whenever possible, these trips should correlate with the unit of study at hand.

Pupils should be under strict disciplinary control during the entire trip from beginning to end. Definite rules should be set up, agreed upon and adhered to for the purpose of safeguarding the physical safety of each individual pupil and in order to insure maximum educational benefits for the entire class. These rules can be formulated democratically by means of class discussion when the trip is planned. Roll should be taken at least once, preferably at the end of the trip. If buses are employed it is helpful to assign each pupil a number and all should be required to give them in rotation : 1, 2, 3, 4, 5, etc., after the bus has been loaded and before leaving the school building. The same routine should be repeated before leaving the establishment visited to return to the school. In case private cars are used, certain pupils should be assigned to each car and the driver should be held responsible for his passengers. It is preferable to have teachers or parents do the driving. If walking is decided upon, or if street cars are used, special directions should be given and pupil monitors should be appointed to watch for traffic hazards.

The teacher is responsible for the conduct of the pupils while in the establishment or factory visited. The teacher should have a preliminary conference with the guide or guides in order to get their coöperation in securing proper conduct. Most guides are eager to help by announcing regulations and cautioning against hazards. A good practice is to have the guide take the lead while the teacher follows up the rear. This helps to prevent laggers from getting separated from the group. Pupils often unconsciously become absorbed in observing a certain machine, and as a result get lost from the group. The handling of materials and souvenir collecting should be rigidly controlled. Abuses of this privilege are the great-

est causes for destroying good relationships between factory management and the schools. Confidence lost in this manner results in refusal on the part of establishments to permit school excursions.

Voluntary Field Trips. Voluntary field trips have many advantages over those of the required type. In the first place, motivation is stronger for the participants because pupils take part in the activity as a result of a felt need. This increased interest permits more freedom and results in greater enjoyment on the part of the pupils and teacher. Less preliminary preparation is necessary and note-taking and follow-up may be placed on a voluntary basis. The increased freedom tends to foster an atmosphere in which teacher and pupils have an excellent opportunity to become acquainted with each other and develop a wholesome respect and personal feeling.

It is possible for pupils to organize their own small groups which can make field investigations of their own accord without being accompanied by the teacher. Such committees can make these trips after school or on Saturdays. The number of members of a committee should generally be less than five. The teacher may give the chairman of the committee a letter of introduction with the names of the members of the committee in order to prevent non-approved members from joining the committee, thereby making it too large. The committee should present a list of guiding items or questions, answers to which they are expected to bring back to the class.

Places which these interested pupils may visit are the local radio station, weather bureau, city water plant, local theaters, sewage disposal plant and the like. It is well for the teacher to contact key persons in these places and get their coöperation in receiving these inquiring youngsters. Generally, some child is personally acquainted with these persons and the proper rapport is established. It is satisfying to hear the very enlightening and interesting reports which these pupils can bring back to the class or club. This procedure tends to employ the natural social grouping of young children in directing children to worth-while activities. It has been found to work exceptionally well with ninth-grade children. The teacher should get written notes from the children's parents approving participation of the child in the activity. Pupils frequently

can persuade parents to take them on certain investigations on the regular Sunday afternoon drive.

STUDY QUESTIONS

1. Give the characteristics of a good demonstration.
2. What are the arguments opposing the abandonment of the laboratory method of teaching science?
3. Describe the procedure in pupil demonstrations.
4. What are the disadvantages attached to field trips?
5. Give the procedure which should be followed in conducting an effective field trip.

ADDITIONAL PROBLEMS AND PROJECTS

1. Present to the class a summary of a few of the most recent studies on the controversy of teacher-demonstration versus individual laboratory.
2. Critically evaluate a field trip in which you have participated as a pupil, and suggest ways in which the trip might have been improved.

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13

Evaluation

Evaluation of the work done during the unit is an essential phase of the administration of a unit in science or any other subject. There has been considerable discussion against the use of the traditional idea of testing in a formal manner, and many advocate an informal subjective evaluation of their own work by the pupils with the help of the teacher. It is the writer's opinion that the informal pupil-evaluation of his own work with the help of the teacher is more feasible in the elementary grades than in the advanced grades of the secondary school. It is true that the pupils at all times do a certain amount of subjective evaluation, even though the formal tests are employed. Pupils should be taught or encouraged to do their own evaluating, even though some other means of evaluation is used.

TYPES OF EVALUATION

There are several types of tests which may be employed successfully in evaluating the achievement of a pupil in science. They are: (1) The Objective type of examination, (2) The Semiobjective, (3) The Pragmatic, or Application type, (4) The Subjective type.[1]

Objective Tests. The objective type of examination seems to adapt itself well to all science subjects, and appears to be the most efficient means of evaluating both because of the adequacy of sampling and economy of time. Objective tests have to be constructed properly in order to be effective because improperly prepared tests of the objective type are practically valueless in evaluating the growth of a pupil.

In order to be constructed properly, an objective examination must fulfill the following specifications:

[1] See Appendix, p. 257, for illustrations of each type of test.

1. It must be valid; that is, it must test what it is supposed to test. The items must be well selected and cover the points which the instructor has attempted to teach, or the objectives which are considered significant.

2. The test must be reliable. Reliability may be achieved by the length of the test or the number of test items which the test includes. True-false items should number at least 40 or 50 in order to be reliable, and the unit examination should be composed of in the neighborhood of 100 items. Through experimentation with the length of objective examinations in science it has been found that junior high school pupils in general science can cover 100 items in approximately 30 minutes, and about the same speed has been found for pupils in biology, chemistry, and physics in the senior high school. If time permits, it may be desirable to have a longer unit examination which will require in the neighborhood of 40 or 50 minutes. Short objective examinations composed of some 10 to 20 true-false items are practically valueless because reliability is too low. Adequate sampling is impossible with so few items.

3. A mastery examination should care for individual differences. This criterion is justified from the administrative point of view rather than from the measurement point of view. From the disciplinary and administrative point of view it is desirable to keep all pupils busy during the whole test period. As we know that the bright pupils in the class will cover as much as three times the area covered by the slow pupils in the class, it is very desirable that there be provisions in the test to keep the bright pupil busy until the slow pupil is able to complete the minimum essentials of the examination. This may be done by lengthening the examination and by calling time on the test as soon as the first pupil completes all the items provided. This method has the disadvantage that inadequate sampling is made of the slow pupil because in many cases he is unable to complete the minimum essentials of the examination. Frequently, the slow child will have completed only approximately one-third of the items by the time the brightest pupil in the class completes all the items. A second plan is to construct a test which all pupils are expected to finish, and provisions are made for the bright pupil by the addition of items which are graduated in difficulty. It has been found that this plan provides adequately for in-

dividual differences without excessive lengthening of the examination. These items may be in the form of a list of from 15 to 30 definitions—a challenging problem which involves a great deal of critical thinking and analysis, or several problems of graduated difficulty.

4. An objective examination should be constructed so that the routine of scoring is cut down to a minimum. It saves a great deal of time to arrange the responses so that the key may be laid alongside the test sheet and be checked more or less automatically. It has been found that the notations of + for true items and 0 for false items makes for greater accuracy in writing a test and scoring it with the assistance of the pupils. Multiple choice items should employ numbers written along the margin of the paper, plus the underlining of the proper responses. This provides for ease in scoring and accuracy of the responses. The matching type of item lends itself to ease and accuracy in scoring.

5. The items should be as brief as possible because it enables the teacher to include many items to be given in a certain length of time, as it takes pupils less time to read short items than long items. Short items usually are easier to comprehend, especially for junior high school pupils. Long items tend to become involved and confusing. Short items tend to use less paper and effect economy, both in the use of paper and stencils.

6. The unit examination should be improved and revised frequently. It is impossible for a teacher to prepare a new mastery examination for every unit each time this unit is taught because the time consumed in constructing the examination is too great. For this reason, the examination should be kept and may be used for one or two years and then revised and improved in the light of experience with the test. In this manner, very excellent and reliable instruments of measurement can be developed over a period of years.

7. Directions should be complete and simple so that pupils are not handicapped by wrong performance due to misunderstanding of directions.

Tests should not be permitted to remain with the pupils because they are rarely of any value to the pupil after the remedial work has been done, and they serve only to be passed to other pupils and

to be used as cribs. The tests, therefore, should be collected and destroyed. Sample copies and stencils should be kept under lock and key. In order to avoid the possibility of tests getting into the hands of the pupils and being passed around, the teacher should be careful that no extra copies of the test are given out during the administration of the test. This can be done by carefully counting out the copies to correspond with the number of the pupils in the class.

Semiobjective Examinations. This type of test generally takes the form of definitions, identifications, and the like. Such an evaluation is convenient and effective when a teacher has insufficient time for the preparation of a comprehensive objective examination. This type of examination may be either mimeographed in form or copied on the board. Such a test is not so satisfactory as the comprehensive objective examination, but may be employed in an emergency and produces satisfactory results. The Semiobjective type can provide for the checking of approximately 75 learning products during a period of 40 minutes and may be quite satisfactorily checked by the pupils in the class.

The Pragmatic Type. The Pragmatic type of examination may be described as a project which the pupil would undertake, wherein the information which the pupil achieved during a unit will find application. The degree to which the pupil has achieved growth will be indicated by the success with which this project is executed. The project may consist of the identification of certain elements contained in an unknown sample in chemistry; assembling, repairing, or building a radio or household appliances in physics; or the identification of specimens in biology. This type of examination has a few disadvantages: (1) The time consumed is much greater than for any other type of evaluation. (2) The evaluation tends to become highly subjective because the rating is done by the teacher primarily from observation. (3) There is considerable difficulty in finding space for these people to pursue a project of this nature.

Subjective Type Examination. The essay and socialized form of evaluation may be considered as the subjective type. The Essay type of examination is the least satisfactory means of evaluation of growth in science subjects. There are two primary objections: (1) It takes a great deal of the pupil's time to write, which consumes time that could be more economically used for the checking

of information or growth on the part of the pupils. A test in science should not be primarily an exercise in writing or composition. (2) A great deal of time is consumed by the teacher's checking, and the evaluation necessarily is highly subjective.

Occasionally, a Subjective type of question may be used as the supplementary portion of an Objective examination. This may help to keep the bright child busy during the test hour, and the disadvantage of the excessive time consumption in checking is somewhat minimized because only a few pupils may have time to do much with these items.

A type of evaluation which may be employed occasionally is the socialized evaluation. In this procedure, pupils discuss, with the help of the teacher, the weak and strong points of the achievement resulting from the learning activities pursued during the unit and democratically determine what remedial measures will make for more satisfactory outcomes. This evaluation may include the contributions of the teacher as well as the activities of the pupils.

CHECKING OF TEST PAPERS

The burden of checking examination papers, as has been the practice in the past and to a great extent at the present, causes many teachers to avoid giving examinations. This results in a lack of sampling of the pupils' work because teachers tend to give an examination only when the data are necessary for the purpose of making out grades. This is not as it should be, because good teaching necessitates frequent evaluation, and adequate grading of pupils requires adequate sampling of the pupils' work. Because of the limited funds for education and the greater demands on public funds for other social services, the tendency is toward larger classes and increased loads on teachers rather than the reverse.

Because of these larger classes and increased teacher loads and the necessity of constant checking of pupil progress, there is definite need for the employment of a system whereby the burden of checking test papers may be shifted from the teacher to the pupils. This is in harmony with the modern philosophy of education that pupils should have an active part in the evaluation of their work. A large percentage of our conscientious teachers is spending a

great deal of time and energy in checking test papers, time that might be better spent in planning and recreation. A large factor contributing to success in teaching is the ability of the teacher to administer; that is, to delegate to the pupils routine work which they are able to execute efficiently.

The average unit in the secondary school continues for approximately two weeks. Each teacher usually teaches five classes with at least 30 pupils in each class, making a load of 150 pupils. Many teachers have as many as 170 to 200 pupils in some junior high schools. If a mastery test is administered every two weeks on the average at the end of each unit, and if the mastery tests are to be valid and reliable, requiring in the neighborhood of 100 items, it means that the teacher has to check 15,000 to 20,000 items each biweekly period. This routine work is devitalizing to the teacher, resulting in poorly prepared and poorly administered lessons. The teacher should be utilizing this time and energy for the preparation of instructional materials and for recreation and rest, so that he will return to school each day full of vitality and enthusiasm. No human being who frequently stays up until midnight or later checking papers can retain the health and vigor necessary to cope successfully with 40 dynamic creatures for six hours each day.

Some educators may feel that pupil checking of papers deprives the teacher of the beneficial effect of knowing better what his pupils know or can do, thereby losing valuable diagnostic aid. The teacher can, however, readily determine pupil difficulties by glancing through the pupil-checked papers and effect remedial work. The pupil checking method conserves teacher energy without appreciably losing instructional benefits and, in addition, gains pupil participation which is educational if handled properly.

This undesirable situation may be remedied by a workable plan which may have the value of activity and educational merit. To a large extent, this routine work may be delegated to the pupils. There are two chief obstacles which confront the successful operation of the technique of pupil checking of examination papers, namely, dishonesty and inaccuracy on the part of the pupils.

A study was made by the writer which attempted to develop and evaluate a plan of pupil checking. Studies on teacher checking of examination papers revealed that an average error of 1.5 per

cent is made in checking between 60 to 100 test papers of the objective type.[2]

Procedure of the Study. This study was conducted over a period of three years by the writer and senior students in the secondary education department of the La Crosse State Teachers College who were engaged in student teaching.[3] A certain phase of the study was completed each year. The entire study was conducted in the field of chemistry.

Type of Tests Employed. Objective tests composed of 100 items were used to facilitate the reduction of figures to percentages. At least 50 of these items were true-false items and the remaining items were of the multiple-choice type. For the purpose of determining the amount of accuracy and potential dishonesty of each group, plus and minus responses were employed for the true-false items and placing of numbers corresponding to the response in the multiple-choice portion of the test. Plus and zero responses were employed for the true-false items and underlining of the multiple-choice situations was added during the second phase of the study when pupils checked their neighbors. The same type of responses were employed for the third phase when the pupils exchanged papers with the persons sitting behind or in front of them, i.e., those who were not their friends. In addition, the checkers were required to cross out items which were left out and sign their names on a designated place on the paper.

Procedure in Administering and Checking. A different group of pupils was employed in each of the three parts of the study. In order to control this factor, a preliminary test was administered to each group to determine the amount of inaccuracy due to carelessness or dishonesty which could be credited to each group. There were at least 60 pupils involved in each phase, employing two or four classes in chemistry which were open to juniors and seniors.

During the administration of the tests, the pupils were allowed enough time to finish the entire test and time was called when the slowest pupil had completed all the items. Provisions for individual

[2] Unpublished study made at the University of Minnesota High School: Table 1, Column 6.

[3] Thomas Shinko, Val Sonsella, Karl Farwell, Ewald McCoy, Willard Turner, Robert Roellig, John Gerletti, Willard Hanson.

differences were effected by additional material placed upon the blackboard, for which extra credit was given. This tended to keep all the pupils busy during the entire test period. Where the potential amount of dishonesty and carelessness was determined when pupils checked their own papers, the responses were read rather slowly, giving maximum opportunity for changing responses. But in the controlled portions of the study, the responses were read as quickly as possible so that pupils would have less time to make dishonest changes.

The test papers were collected at the end of the period and then handed back to the pupils for checking the following day. In the meantime, the student teachers recorded each response to every item on each test sheet on squared graph paper. After the pupils had checked the papers the following day, the assistants again recorded the responses and checked the papers. This would reveal the actual number of changes and the number of errors due to carelessness.

RESULTS. 1. The percentage of error found when pupils checked their own papers, using plus and minus responses for the true-false items, ranged from approximately 7 to 8 per cent. The percentages were 6.59, 8.10, and 7.58 for groups I, II, and III, respectively. These figures show that each of the three groups had approximately the same tendency toward dishonesty and inaccuracy.

2. In group I, which was composed of 153 chemistry pupils, it was found that an average error of 4.49 per cent occurred while they checked their neighbor's examination papers requiring plus and minus responses.

3. When plus and zero responses were required, the percentage of error was reduced to 3.24, while 136 pupils in group II checked their neighbor's paper.

4. In group III, the percentage of error was reduced to .61. (1) Plus and zero responses were employed for the true-false items; (2) underlining was required for the multiple-choice items; (3) the pupils were required to make a check before all unanswered items; (4) the checkers were required to sign on a designated place on the paper; (5) they exchanged papers according to specifications. This is slightly over 1 per cent less than the teacher errors of 1.75 and 1.35 per cent found to occur in checking two groups of

Table 1

ERRORS IN CHECKING EXAMINATION PAPERS

Part of*	No. of Pupils	No. of Items	No. of Errors	Percentage of Error	
				Pupil	Teacher
1	2	3	4	5	6
I. Checking Own	153	15,300	1,062	6.94	...
Neighbor's	151	15,100	678	4.49	...
II. Checking Own	136	13,600	1,102	8.10	1.75
Neighbor's	136	13,600	440	3.24	1.35
III. Checking Own	64	6,400	486	7.58	...
Exchanged	60	6,000	37	.61	...

* In Part I of the study, plus and minus responses were employed for the 80 true-false items. In Part II, plus and minus responses were employed where pupils checked own papers, and plus and zero when checking their neighbor's papers. In Part III, plus and minus were used in checking own paper, and plus and zero when pupils exchanged according to specific directions. The checker signed his name on a specified place on the paper and blanks were crossed out.

136 papers each. Approximately half of the errors were due to cheating; that is, deliberate changes in responses by the checkers.

5. Two significant observations resulting from this may be worthy of mention: (1) Pupils tend to cheat less and to be more accurate in checking their neighbor's papers than in checking their own papers. (2) Bright pupils tend to cheat, although not to so great an extent, as pupils of less ability. The correlation between honesty and I.Q. for 75 pupils was found to be .324; and between grades in chemistry and honesty it was .311.

CONCLUSIONS. 1. Pupil checking of objective type examination papers can be done as accurately or more accurately than teacher checking if the work is controlled. Plus and zero responses must be employed with true-false items; pupils must be required to exchange papers with other than friends; blank items must be crossed out before checking begins; and the name of the checker must be placed on the paper so as to make the pupil personally accountable for the checking.

2. Pupil checking of their own papers results in scores which are too unreliable for just grading of pupils.

3. Controlled pupil checking of papers may have many desirable advantages. It makes possible more efficient teaching because: (1) Pupils can secure a prompt evaluation of their work; (2) remedial work can be done at the most effective psychological moment; (3) the teacher is able to spend his energy and time preparing more effective lessons; (4) the teacher's vital energies can be conserved; (5) learning can be made more satisfying to the pupils. Furthermore, the pupils are given an opportunity to have a part in the evaluation of their work.

GRADING OF PUPILS

Grading of pupils has been a controversial problem for many years. There are many schools of thought on this subject, ranging from those who believe that there should be no system of grades to those who maintain that a highly differentiated system of grading is desirable. The term "Grade" throughout this discussion means a symbol, whether it be a letter or number, which gives a key to the quality of work done or the degree of growth achieved on the part of a pupil while engaged in the learning experiences in science which are permitted or provided for the pupil under the supervision of the teacher. In a majority of school systems, whether large or small, such evaluation of the pupils' work is necessary for each unit, problems within a unit, tests, and for the work during the semester. Science subjects tend to lend themselves readily to objective and reliable evaluation.

Evaluation of the Work for the Unit. In order to secure a reliable evaluation of the accomplishments of a pupil during a unit in a science subject, it is necessary to make evaluations of the component parts of a unit such as the individual problems in the unit and the unit examination; also, it is necessary to make the unit grade a composite of these measures. Grading of the individual problems in a unit may be evaluated on a subjective basis. The judgment may be made more reliable by grading each part of the problem assignment which may be divided into three levels, as described in Chapter 8.

If a pupil completes Assignment A satisfactorily, he may be given a grade of C or 3. If the pupil completes the second level of the assignment, which may be designated as Assignment B, the

pupil may be given a grade of B, or 2, on the work completed thus far. And finally, if a pupil completes in addition to Assignments A and B the activities provided under the highest level of activities, Assignment C, he may be awarded a grade of A, or 1, on the class work connected with the specific problem. Assuming that the unit is made up of three problems, each of the three individual problems may be evaluated in this manner and the unit class grade can be the average of the three grades received on the problems.

Before the final grade for the unit can be determined it is necessary to include the grade on the unit test. The test grade may be determined by means of an objective test and by employing the distribution technique. The more common practice is to employ a five-point system of grading, A, B, C, D, and E, or 1, 2, 3, 4, and 5. The upper and lower limits of the grade may be determined empirically by inspection or by the standard deviation method. Teachers should be able to employ the standard deviation method, but in actual practice it is found impractical for use in the grading of unit tests because of the excessive time required to calculate the standard deviation. It may be desirable to employ the standard deviation method for the grading of pupils on results of semester examinations if the scores for two or more classes are grouped together. For groups under 60, the method is unreliable and can be employed only as a guide.

Determining the limits of the respective grades by inspection is accurate enough for practical purposes. The time consumed is practically negligible as compared with the former method described. A distribution of the scores can be made, using from 10 to 15 intervals, generally employing an interval of five points. For illustrative purposes, the scores on a test permitting a maximum score of 110 points and a possibility of 100 points on the required part of the test may be used.[4] The distribution may come out as follows: three scores of 100 points or more; eight scores between 90 and 99; fifteen between 75 and 89; seven between 65 and 74; and three at 64 or below. The teacher can assign three grades of A; eight of B; fifteen of C; seven of D; and three of E. If numbers are preferred in place of letters, a grade of 1 may be used instead of the A, 2 in

[4] See p. 146 for description of the type of test.

place of the B, and so on. For convenience in averaging, numbers are preferable to letters.

Frequently, it is practical to assign these grades without the routine of tabulating the scores. With continued experience, the teacher can glance through the scores on the papers and arbitrarily make the limits with satisfactory success.

It is satisfying to the pupils to get an idea of their grades at the end of the test period. This can be done in a minute or two. After the papers have been checked, by pupils exchanging papers,[5] and the pupils have had their papers returned to them for rechecking, the teacher can say, while writing the figures on the board, "How many received a score of 100 or more?" Three hands are raised. Then the teacher may say, "How many received a score between 90 and 99?" and so on. It is obvious that the pupils can get a tentative idea of their grades on the test. The teacher should, of course, look over the papers, especially those which have been checked by pupils who may be suspected of dishonesty. If errors are found, it is wise to call it to the attention of the pupils who scored such papers. This procedure may serve to develop character in that it may tend to correct tendencies toward dishonesty. Some teachers may argue that pupil checking tends to foster dishonesty, but it is the belief of the writer that honesty is developed through an opportunity to practice it just as other types of learning are achieved by practice.

Unit tests may be used profitably as a basis for remedial work. This procedure employs the sound principle of learning termed as "Readiness." After putting forth their best efforts to solve a problem presented in a test, and after having failed to solve this problem satisfactorily, the pupil is literally ready "with his mouth open" to receive the correct solution. The child is more likely to retain the correct concept or solution when it is received under these conditions. It is considered advisable to discuss every false item in the true-false portion of the test to clear up any misconceptions which pupils may have regarding them. An excellent approach is to teach the pupils why these statements are false.

Pupils should be given an opportunity to contest any item in the test, the grade on the test, and unit grade which the teacher may

[5] See p. 203 for method of checking.

give. This procedure makes it mandatory that the teacher secure as much data on the work of the pupil as is practically possible. If the pupil can show that the grade should be changed, the adjustment should be made. This procedure preserves the mental hygiene of the child as well as his personality and attitude.

Determination of the Unit Grade. If grades are to be employed, it is important to prepare them with great care. It is inexcusable to rely upon the judgment at the moment the grade is made out because it is practically impossible to recall accurately the performance of each child without some definite record of the respective evaluations of each problem, especially for the normal load of 150 pupils who come under the guidance of a teacher in the average secondary school. It is necessary to adopt a definite procedure which can be explained to the pupils at the beginning of the course.

It may be helpful to describe in detail a procedure which is within the capacity of the average teacher and can be understood by the pupils. Let it be assumed that the unit is composed of three problems. The teacher has the following recorded grades in his classbook for a certain individual: For problem I the grade is 2 +; for problem II, 3; for problem III, 2 —; and for the test the grade is 2. What shall the grade for the unit be? It will be necessary to adopt certain arbitrary figures to represent the plus and minus grades. It has been found practical to represent 2 + as 1.7 and 2 — as 2.3. In averaging these three grades, one would add 1.7, 3, and 2.3, and divide the sum by three to determine the grade for the class work. This totals 7.0 divided by 3, or 2.3, which may be interpreted as a grade of 2 —. It may be a good practice to count the class work as two-thirds and the test grade as one-third of the final grade. Therefore, the final unit grade can be found by adding 2.3, 2.3, and 2. This total equals 6.6. Dividing 6.6 by 3 equals 2.2 which can be interpreted as a 2 —.

STUDY QUESTIONS

1. Why is subjective evaluation of their own work by pupils inadequate for the secondary school?
2. What are the characteristics of a properly constructed objective examination?
3. How may individual differences be cared for during an objective examination?
4. How may the task of scoring be reduced in the objective examination?

5. Under what conditions may semiobjective and essay types of examinations be justified?
6. What are the advantages and disadvantages of pragmatic tests?
7. Describe in detail a procedure which may be employed in pupil checking of objective examinations.
8. Describe the procedure which may be used in converting raw test scores into pupil marks.
9. Describe a procedure which may be employed in marking accomplishments of pupils during the assimilation period.
10. Describe a procedure which may be employed in formulating a unit grade which is an equitable combination of the grades achieved on the class work of the unit and the test grade.

ADDITIONAL PROBLEMS AND PROJECTS

1. Using the raw scores achieved from the administration of an objective examination to a group of pupils, convert them into a five-point grade system, first by using the empirical method, and compare that with the results achieved by the standard deviation method.
2. Formulate a unit grade for a certain pupil, using the grades from three problems and a unit test. The relative weights of the class work and the test grade shall be two-thirds and one-third, respectively.

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UNIT FIVE

Supplementary Factors in Science Teaching

Supplementary factors in increasing the efficiency of science teaching in the secondary school may be grouped as follows: (1) Science clubs; (2) teaching aids, such as moving pictures, slides, exhibits, radio, and the like; (3) specialized science rooms and equipment; (4) guidance as a part of science teaching.

Science clubs serve as an effective means of motivation and enrichment in science teaching. Worth-while activities which are unsuitable for the regular classrooms may be experienced through the science club. Field trips may be limited to such groups of common interests. In addition to enriching the experiences in the area of science and concomitant areas, functional vocational guidance may be effected. Actually, vital contributions may be made in the total development of the pupil.

Moving pictures have proved to be an effective teaching aid which has abundant resources in the area of science teaching. The radio has excellent possibilities as a vitalizing agent. Detailed suggestions as to effective methods of utilizing these teaching aids as well as the proper use of slides, exhibits, and charts are presented in this unit.

Proper physical surroundings such as adequate and appropriate rooms and equipment are important factors in effective science teaching. Special adaptations with reference to type of science subject and size of school are desirable. A science teacher should be prepared to make recommendations and plan these phases of a school building.

The science teacher has excellent opportunities to guide the pupil toward the right vocation. The very nature of the subject and technique of instruction, such as those employed in the laboratory and during any directed study period, makes it possible for the teacher to observe aptitudes and interests of the pupils. Many phases of guidance in which the science teacher is expected to participate are presented in the last chapter of the unit.

14

Science Clubs

Science clubs may be of many different types, in various grades, and in several science subjects. In a junior high school, it may be most desirable to include the area of all science fields and call the club generally a "Science Club," though Nature Study Clubs, Bird Clubs, Aviation Clubs, and the like have been very successful. In the senior high school, they may be Conservation, Chemistry, Radio, Photography, or similar clubs.

Objectives and Values. One of the main objectives of a science club may be to motivate the study of a particular phase of science through the applications of science. One objection to our present plan of education is that it tends to be too academic, with too little opportunity for practical application. The club may serve as a means of revealing the practical applications of the science subjects to the pupils through field trips, special experimentation, or special study.

Opportunities for advanced or extended study in various fields of science may be provided through club organization. Many areas of science cannot be studied in high school because of the limited abilities and interests of high school pupils. Pupils often are capable of doing extended study in scientific areas which cannot be conveniently studied in the classroom. For a group of certain individuals who are disposed to further study, the clubs may help to provide for this need. This opportunity for the pursuance of special interests by selected individuals helps care for individual differences in the science program.

Guidance Through Clubs. Clubs may be very effective in educational and vocational exploration or guidance. Vocational guidance may be effected through the special study by club members of certain phases of applied and pure science which they might be interested in pursuing as a life work. In a chemistry club which the writer sponsored for several years, pupils were given an oppor-

tunity to visit industries in which chemistry was applied and which were located in the city and surrounding area. Besides industries, they visited state medical laboratories, and city laboratories in local hospitals and clinics. In addition, interested members of the club could make an annual visit to the research laboratories, medical laboratories, and x-ray laboratories of the world-famous Mayo Clinic at Rochester, Minnesota. Boys who were interested in chemical engineering and research had an opportunity to observe at first hand the nature of the work and conditions under which the work was carried on. The same was true in the field of medicine and medical technology. Girls who were interested in nursing and medical technology or medical research had an opportunity to observe first hand the conditions and the nature of the work. Observations of this activity over a period of years revealed that the participants received a great deal of practical help in their choice of vocation.

Considerable help in educational guidance was achieved also because during these visits the pupils asked the guides and the people who were employed in this specialized work questions regarding the type and the amount of training necessary to prepare for these professions. Opportunities for advancement and the amount of salary which could be expected also were determined through the interviews.

Science clubs provide an opportunity for pupil activity, training in leadership, and self-expression. A fundamental principle in mental hygiene and psychology is that a person's full ability rarely is expressed unless he is vitally interested in a certain activity. Leadership may be developed in almost any type of person, providing it is in an area where the person is interested and excels.

A closer personal contact with the science teacher is possible through club activities. Persons who have been active in the teaching profession for a considerable length of time discover that a teacher seldom becomes acquainted with, or gets to understand and know, a pupil in the atmosphere of the average classroom. The free and informal atmosphere of the club period and activities permits a child to break down the reserve which generally covers up his true nature. This informal and free attitude develops a more personal feeling and loyalty between pupil and teacher which is desirable.

From the social point of view, the club fosters school spirit and loyalty to the school and the group, develops coöperation, and permits the spirit of service. Nearly every club in a school has as one of its major objectives the improvement of the school community. This activity tends to promote a conscious responsibility in attempting to influence other pupils in coöperating for the betterment of the school.

The science club provides for the study of applications of science in the areas of industry, medicine, meteorology, biology and the like. Generally, it is inconvenient and impractical to project the study of science too extensively into the practical applications, both by means of extended reading and field trips. The club affords the possibility of these extensions in study for a selected group which feels a need for this enrichment material. The majority of pupils in any one high school subject tend to be interested in achieving very little more than the minimum requirements.

Source of Members. Members for science clubs may be secured from three different sources, namely: (1) The whole class. (2) From one subject alone, such as chemistry, physics, or biology. (3) From all fields of science.

When one whole class is used as a source of membership, the class usually meets after school to carry on further study which is not possible in the limited time afforded by the class period. This is not a very frequent source of membership because it is seldom found that a whole class possesses enough interest in that subject to continue spontaneously in additional activities in the field. In the larger schools, club memberships frequently are secured from the pupils in one subject area because the opportunities for the study of practical applications and more intensive investigation into the pure sciences are plentiful. For example, the applications of chemistry are extended into the areas of industry, medicine, biology, and meteorology. Practically the same applications are found in the field of physics, while biology has an unlimited scope of applications. In the junior high schools where general science is required, it is obvious that the membership in the science club is taken from the class in general science.

Membership from the whole school is the most frequent practice in the organization of science clubs. This is applicable to small

or large schools. Generally, these clubs follow the areas of radio, conservation, nature study, and bird study.

Time of Meeting. Clubs may meet after school, during school time, or during the evening. For secondary school purposes, it is considered undesirable to have club meetings in the evening because of the moral hazard of having small group activities in the school building at that time, and because of the hazard of having pupils walk home long distances after dark.

A club period during school time has been found to be very effective and desirable, especially in the junior high school and, in many cases, in the senior high school. An activity period during school time avoids conflicts with multitudinous activities after school and, to a great degree, tends to ensure the success of the club activities. A second advantage is that it tends to prevent the over-participation of many pupils in extracurricular activities because if all activities are held at a certain period during the school day, it is impossible for a pupil to participate in too many activities merely for the notoriety or recognition which is received through belonging to many clubs. It is possible to have certain clubs or groups meet after school even though an activity period is provided during school time. This gives an opportunity for pupils who desire to participate in additional activities to do so. For clubs which have field trips as a part of their activity, meeting during school time is very desirable because after school most factories and other industries are closed for the day. On the other hand, biological field trips, or those which take a considerable length of time, may be more appropriately conducted after school.

Function of Adviser. The adviser of a club should be an influential person behind the scene. Members of a club should be given every opportunity to administer their organization. A dominant adviser stifles initiative, interest, and spontaneity on the part of the members until it eventually becomes nothing more than a teacher-dominated class period. This type of atmosphere defeats the whole purpose of a club. It should be remembered that the club is the pupils' organization in which they are free to do as they desire unless the trend of events becomes undesirable, at which time it may be necessary for the adviser to assert more influence.

It is frequently necessary for the adviser to effect positive leadership when the membership seems to be at a loss as to what to do, if the interest seems to dissipate, or if adverse forces or dissention tend to disintegrate the group. If the club is composed of a good membership, if the adviser is on the alert to detect minor undesirable conditions, and if he promptly assists in correcting them, it is seldom necessary for the adviser to assert this positive leadership.

The members of a club should be permitted to govern and initiate all activities. If the adviser continually makes suggestions and criticisms, the members become willing to let him perpetuate. This makes the members recessive and docile without applying their critical thinking and action. It has been found through experience that, even in junior high school, if pupils are permitted to govern and initiate, they will do so very successfully. Frequent mistakes may be made, but that is the manner in which pupils learn to govern themselves. Self-government on the part of pupils is one of the primary objectives of a club; therefore, an opportunity for this achievement should be provided.

Activities. To suggest all the activities which may be successfully pursued in all types of science clubs is impossible, but it may be helpful to list a few.

1. Field trips may be made to industries in the community, to dairies, health laboratories, hospitals, storage plants, ice manufacturing plants, and the like. Geological and biological field trips are possible in the neighborhood of every community.

2. Preparation and presentation of assembly programs can be accomplished by members. It is most desirable that these assembly programs grow out of activities of the club. This preparation for a final presentation provides strong motivation for the pupils to do excellent and thorough work. Pupils have been found to be able to plan, prepare, and present programs which are more acceptable to the pupil body than those in which the teachers have had too great an active part.

3. Advanced experimentation is an activity which seems to be appealing to members, especially in physics and chemistry clubs. Many pupils develop an intense interest in experimentation during their regular class work, and limitations of time often prevent

full satisfaction in this activity. The club serves as a means of extending this opportunity.

4. Discussion of field trips is a very vital activity in science clubs. Generally, it is beneficial and advisable to discuss the field trip before the trip is made and then discuss it again afterward. The discussion which prepared for the field trip may be developed by a member of the club or by a committee. Such a discussion can very readily consume an entire club meeting. Usually, it is found advisable to see that some member of the club is appointed to take notes during the field trip which can be used as a basis for this discussion after the trip or for a write-up for the school paper.

5. Study and discussions of scientific topics which are current and vital serve as a dynamic activity for science clubs. The club may develop its own library which may be maintained in the science room or in the "Club Corner" in the school library. Individuals or committees may prepare reports on scientific topics and act as discussion leaders in these areas during the club meeting.

6. Outside speakers are a stimulating force in promoting the success of the club program. Care should be exercised to see that outside speakers do not monopolize the entire activity of the club since this would tend to deaden the initiative of the members. Activity on the part of the members is necessary for maximum growth. Persons who may be brought in for occasional talks and discussions before the club are the County Agent, members of the Biological Survey, game wardens, engineers, the County or City Health Nurse, the school doctor, the manager of the local electric light plant, and the like.

PROCEDURE IN ORGANIZATION. Pupils frequently tend to exhibit the need for a certain type of club by bringing a request to the science teacher for a radio club, a nature study club, or a club which provides additional activity. The science teacher should take advantage of such an opportunity and should give the pupils every encouragement by aiding them in the organization of a club for whatever purpose they desire. Occasionally, a teacher must take the initiative. It is erroneous to believe that initiative of pupils is always necessary in effecting an organization. Teacher-initiated clubs and activities have been found to succeed as readily as pupil-

initiated activities. That the interest and support of the adviser is paramount in the maintenance of a successful club is an accepted fact. It has been found that pupils are unable to continue effectively unless the adviser exhibits interest and offers aid when necessary.

The procedure that was followed in organizing a science club in a junior high school may be helpful and of interest. An announcement was made in each of four general science classes that all pupils who were interested in organizing a science club should meet in the science room immediately after school. Approximately 25 pupils responded to the call.

The teacher explained some of the major purposes of such an organization and made some suggestions as to what activities might be carried on. A temporary chairman was elected and a constitution committee was appointed. The instructor had secured a constitution from the *Popular Science Monthly* magazine. This sample constitution was given to the chairman of the constitution committee. By the next meeting scheduled for the following week, the constitution committee had a proposed constitution prepared. It was interesting to note that the sample constitution merely served as a guide and that pupils critically evaluated every article as to its fitness for their purpose. By the third meeting, the club was fully organized, with permanent officers and standing committees.

During the first year, the activities of the ninth-grade Science Club consisted of several field trips to at least half a dozen industries in the city, preparation and demonstration of experiments, and reports by the club. The club continued on its own initiative, with the adviser in the background at all times. These young ninth-grade pupils arranged for all their field trips without any assistance from the adviser. This club continued to be active for several years, until the instructor left.

A description of the procedure employed in the organization of a senior high school science club may be of help to someone contemplating such a group. This club was called a Chemistry Club, and the membership was chosen entirely from the chemistry classes in the senior high school. The primary objective of this group was to make field trips into the industries found in the city and its environment where chemistry found its application. This necessi-

tated limiting the membership to approximately 25 pupils because of the difficulty of handling larger groups successfully on industrial field trips. In order to secure a high quality of member and to keep the number down to such a comparatively small number, it was decided to limit the eligible pupils to those who achieved a grade of B or better for the last quarter or for the preceding semester.

An announcement was read to all chemistry classes, which numbered six in this school, that pupils who were interested in continuing chemistry as a life work and who had achieved the grade of B or better during the preceding quarter or preceding semester should meet in the chemistry recitation room after school on that certain day. About 25 pupils reported for the meeting and the teacher explained the purpose of the meeting, outlined the objectives of the club, and suggested a possible procedure for the work. About 20 pupils signified their desire to participate in such an organization, and the other pupils were excused and invited to participate at a later date should they be interested.

At this first meeting, a temporary chairman was elected and a constitution committee appointed. During the following week, the report of the committee was presented to the group, criticized, and finally adopted. The committee prepared a constitution with very little help from the adviser except when his advice was sought. The final form of the brief constitution was as follows:

CHEMISTRY CLUB

Preamble

The purpose of this club shall be:

1. To promote interest in chemistry among the pupils of Central High School.
2. To learn the practical application of chemistry.
3. To carry out more complicated experiments than are permitted in regular class work.
4. To provide educational and vocational guidance for its members.

Article I—Officers

Section 1. The officers of this club shall be: (a) President, whose duty it shall be to conduct all business meetings; (b) Social chairman, whose duties it shall be to arrange for trips through commercial plants; to arrange assembly programs; and to conduct the meeting in absence of the president; (c) Secretary, whose duty it shall be to keep an accurate and concise record of members and activities of the club; (d) Pupil-Teacher Council Representative, whose

duty it shall be to represent the organization at Pupil-Teacher Council meetings and to report all decisions made by said organization.

Article II—Membership

Section 1. Membership of this club shall not exceed 20, 50 per cent of which must be boys.

Section 2. After two unexcused absences the members shall be dropped. An excused absence shall be determined by a white pass or adviser's permission.

Section 3. Members, on application, shall be taken in twice a year by majority consent of the organization.

Section 4. In order to be admitted to this club and continue to be a member, the pupil must maintain an average of C in all of his studies.

Article III—Meetings

Section 1. Regular meetings shall be held the ninth period every Friday during the school year.

Section 2. The regular meeting shall be held in the chemistry laboratory.

Article IV—Dues

Section 1. There shall be no regular dues.

Article V—Committees

Section 1. The president shall have the power to appoint all committees.

Article VI—Procedure

Section 1. Roberts' rules of order shall be used as the basis of all business procedure.

Article VII—Amendments

Section 1. Roberts' rules of procedure shall govern the amending of this constitution.

The club met during the last period of the school day on each Friday. There were three reasons for this. First, if an activity is worth-while, it may be justifiably conducted during school hours. Second, the conflicts with the multiplicity of other extracurricular activities were partially eliminated. Third, many of the industrial plants and institutions ceased operations for the day soon after four or four-thirty o'clock in the afternoon.

All visitations within the city and those which were not handicapped by distance were conducted during the regular meetings of the club. Trips outside the city were made on Saturdays or holidays. All visitations were alternated with at least one discussion and preparatory meeting in the regular room in the school building. At these meetings, the group discussed the principles and applications of chemistry which were revealed in the last excursion,

decided upon the next and future trips, and discussed the principles and applications of chemistry to be observed. The club owned a library of 12 books pertaining to the applications of chemistry in industry and to other life activities and nature as well as biographies of famous scientists. This served as an excellent source of information and materials for discussion and programs. Much of the time was spent in planning and preparing programs for assemblies and parent meetings.

The activities for the year may be classified into four categories: (1) Projected study or excursions. (2) Planning of activities and discussion of trips. (3) Advanced experimentation. (4) Planning and presentation of programs.

The club had been functioning long enough to be able to have formulated quite a definite itinerary for the full school year, reserving certain trips for each semester. The semester grouping was desirable because the semiannual promotions provided a beginning group of pupils in chemistry each semester. In this way, pupils were not required to duplicate visitations, and each member, regardless of the time of his admission, had an opportunity to participate in the full schedule.

The schedule followed during the past year, which practically made up the permanent itinerary, may be given as follows:

First Semester:

1. *A rubber mill,* where the following were observed: Raw rubber; compounding; rubber-mixing machines; coating of fabric with rubber; rolling rubber sheets; cutting patterns; complex machines; making of rubber footwear; vulcanization; packing of rubber footwear; chemistry research laboratory, with explanation and discussion of the problems involved in the manufacture of rubber footwear, and the chemist's job in the process. The chief chemist acted as a guide.

2. *A brewery,* which produced malt syrups and beer, gave the members a chance to learn about the following: Fermentation vats; chemistry of fermentation; power house—chemistry of combustion in heating and power; cooling systems; bottling house—sterilization and filling of bottles; production of malt and hops; triple, double, and single effect evaporators; and an excellent research laboratory. The job of chemist in this connection was explained by the chemist who was the able guide.

3. *A modern hospital,* where the pupils were given an opportunity to explore the x-ray and technical laboratories. The x-ray was explained in detail, including production and interpretation of x-ray photography. The fluoroscope

was explained and demonstrated upon one or two of the members of the group. Many technical medical tests were demonstrated, including blood tests, urinalysis, microscopic examination of several microörganisms, and the process of their incubation. A splendid medical museum also was well presented.

4. *The medical laboratories* at the Mayo Clinic at Rochester, Minnesota, gave the most outstanding opportunity of the year for the group to observe the application of chemistry to medicine. A general tour of the Clinic was included. The wonderful Chicago World's Fair Museum captivated the interest of the members.

5. *A patent medicine and food products manufacturing plant* in a neighboring city provided an excellent exhibition of the preparation of extracts, perfumes, condiments, pills, tablets, cosmetics, shampoos, and soaps.

6. *A sewage disposal plant* in the city offered a splendid demonstration of chlorine disinfection, gas formation from bacterial action, automatic control of plant operation, and sanitation processes.

Second Semester:

7. *A modern farm implement factory* gave the group a splendid opportunity to observe the operation of a foundry, pattern shop, the mechanical engineers' plans, electrowelding, polishing and painting of metal parts, and operation of complicated and powerful machinery. The assembling of mechanical devices and the shipping of machines held the alert attention of the group.

8. *A plant which produced heating units and air-conditioning systems* illustrated interestingly: photostatics, blueprinting, spot welding, chemistry involved in heating, processing of metals, and the chemistry of air conditioning. The experimental laboratory and powerful machines were inspected.

9. *A soft drink factory* demonstrated the methods of sanitation in the process of cleansing bottles, preparation of syrups for flavoring, and mechanical filling and capping. The synthetic preparation of flavors and minor employment of chemistry created much interest.

10. *The local gas plant* was outstanding in its contribution to the applications of chemistry. The members of the club saw and heard explained the process of preparing coal gas, water gas, and coke, and of the enrichment of these gases with petroleum oil. The process of purifying these gases challenged the interest of the pupils with its close application. The process of storing and marketing the products was of great educational value.

11. *Two ice cream factories and one milk plant* in conjunction gave a very clear performance and explanation of the process of artificial ice manufacture, ammonia cooling systems, cold storage, testing and pasteurization of many food products, and the manufacture of ice cream. The storage and marketing of these products, including the use of solid carbon dioxide, contributed greatly to the general information desirable for the members.

12. *A modern foundry* gave the pupils an opportunity to witness the manufacturing of a brass or iron casting from the preparation of the mold through the spectacular pouring of the metal, removing castings from the molds, and polishing.

Planning and arrangements for the trips were taken care of entirely by the members and the officers whose duties were so designated by the constitution. The experimentation on the part of the members had not, as yet, been adequately developed except so far as entertaining experiments were prepared for the demonstration programs. The discussions were conducted almost entirely by the members, except when the adviser felt that contributions requiring more experience and knowledge of chemistry than that possessed by the members were needed.

The club generally presented two programs each year, one before the pupil body and another before the Mothers' Club or Parent-Teachers Group. During one year, the portion of the assembly program which was adaptable to the radio was given during a quarter-hour broadcast over the local radio station. The demonstration programs generally were composed of about four talks by the members, some form of music, and about 10 minutes of entertaining experiments, making the total presentation from 30 to 40 minutes. One member acted as Master of Ceremonies. All of the talks, except one by the president, were given voluntarily on any subject in which the member was interested. The talk by the president outlined the purposes and activities of the club, and means of gaining membership. The other talks could be prepared upon subjects such as "The Chemistry of a Loaf of Bread," "The Metallurgy of Iron," or "From Wood to Celluloid," etc., which are of interest to the general public. The music could be of the instrumental type, depending upon the talent available in the club. Novelty numbers such as the production of musical selections by blowing upon test tubes and hammering on bottles, etc., greatly entertain an audience.

The writer feels that the activities of the Chemistry Club were a revelation to the members and to the adviser. They contributed greatly to the department and the school as a whole. A few maxims which functioned well were as follows: (1) Permit members to govern and initiate; (2) the adviser should be an influential person behind the scenes; and (3) the adviser should effect positive leadership whenever necessary.

STUDY QUESTIONS

1. What types of clubs are suitable for the junior high school? For the senior high school?
2. List several objectives of a club program in the science area. How may guidance be effected through a science club?
3. What valuable opportunities are provided for pupil activity through a science club?
4. How may members be selected?
5. At what time of the day may science clubs meet?
6. What is the function of the adviser of the club?
7. List several activities in which members of a science club may participate.
8. Describe a procedure in organizing a new science club.
9. Give the major articles in a constitution which may be functional as a basis for organizing a science club.

ADDITIONAL PROBLEMS AND PROJECTS

1. Describe in detail how you would organize any activities which may be promoted in a community of not more than 2,500 population and not more than 50 miles from a fairly large city.

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15

Teaching Aids

Teaching aids may include such things as charts, slides, moving pictures, pictures, workbooks, models, diagrams, exhibits, and radio.

MOVING PICTURES

Moving pictures, both silent and sound, are considered the most important modern teaching aid. Their value has been practically established through expert opinion and valid experimentation.[1,2] It is important that teacher and administrator become informed about, and make use of, this modern device for imparting knowledge and understanding to our young people. It is a stimulating and vitalizing influence for both pupils and teacher. Many teachers feel that to deprive the pupils of the wealth of films which are available in the field of science and can be correlated with the unit at hand is almost criminal.

Paraphrasing the old Chinese saying, "A picture is worth 10,000 words," one may say that a moving picture is worth 10,000 pictures, and a sound picture a great deal more. Real experiences and worth-while knowledge can be made available for the pupil right in the classroom. A silent or sound picture makes it possible to bring all of nature, human progress, history—in fact, the whole world in all its sociological, biological, and physical phases—to every pupil. A living replica of all that we know about the universe can be brought into the schoolroom for its intensive study. The moving picture, both silent and sound, affords an opportunity to increase our teaching efficiency enormously, and we should lose no time in taking advantage of this teaching aid.

The results of slightly more than 100 separate experiments regarding the effectiveness of the motion picture as an aid to teach-

[1] Roulon, Philip J.: "Sound Motion Picture in Science Teaching," Cambridge, Harvard University Press, 1933.

[2] Arnspiger, V. C.: "Measuring the Effectiveness of Sound Pictures," Bureau of Publications, Teachers College, Columbia University, 1933.

ing, permit the conclusion that "when properly produced and wisely used, the motion picture possesses distinct pedagogical values over and above traditional teaching methods on which the same amounts of time and energy are expended." In the larger part of the experiments reported, children studying by means of the motion picture have learned more than their colleagues who did not have the privilege of this aid.[3]

There has been some speculation whether or not the superiority of the moving picture is due to novelty or fitness of the moving picture in imparting information to the child. Studies to date indicate that the increased achievement through the use of the moving picture over the traditional plan of teaching is not due to the novelty factor but to the efficiency of the moving picture. It seems, therefore, that the moving picture derives its educational effectiveness not from what it is, but from what it can do. It serves also as a stimulus to pupil activity. The merits of the motion picture technique are in its ability to create lasting impressions, to provide clarity of presentation, and to furnish experiment clues by which the subject may be better understood and longer remembered.

Experimental data to date have revealed some valuable information regarding films:[4] (1) Sound on film is found to be superior to a silent film with commentary by the teacher, and the latter method in turn was found to be superior to the silent film. (2) Moving pictures of all kinds, whether they be silent or sound, are effective teaching aids, showing an increased efficiency from 10 to 50 per cent over the other methods of teaching not using the film.

One of the most comprehensive studies on the effectiveness of sound moving pictures in the teaching of science was made by Roulon.[5] This experiment was conducted in three suburbs of Boston which have had a population of 102,000, 36,000, and 72,000, respectively. The experiment was carefully controlled and efficiently administered. Space will not be employed to give a detailed description of the experiment, but its results and conclusions are worthy of at least a partial summarization. The final conclusions of the experimenters may be stated as follows:

[3] Roulon, P. J.: *Op. cit.*, p. 2.
[4] *Ibid.*
[5] *Ibid.*

1. The pupil achievement increase ascribable to the use of the film may be expected to exceed 20 per cent.

2. For the facts and relationships specifically dealt with in the film, the film-caused increase in pupil achievement may be expected to exceed 35 per cent.

3. Neither of the above two gains may be expected to be made at the expense of more important but less definable educational values, such as good habits of thinking.

MOVIES VERSUS FIELD TRIPS. In a preceding discussion, the disadvantages of field trips were cited and a suggestion was made that moving pictures may be employed as an effective substitute. The moving picture eliminates all the disadvantages of field trips and possesses many of the advantages. Out-of-school experiences can be brought to the pupils in a classroom instead of making it necessary to attempt the hazard of taking pupils outside the school building. Films can be more perfectly integrated with the unit at hand and can be presented during the regular school period in the classroom or in a nearby projection room. All pupils have an equal opportunity for gathering the full benefit of the experience. This is not true of a field trip in the majority of cases if the group is relatively large. Purely educational films contain no advertising propaganda, and the projection room is the only limitation on the size of the group or class.

In many cases the films are superior to the careful and the first hand individual study of various plants and animals. Time-lapse photography affords means of clearly divulging secrets which are hidden from the most skillful observer. For example, the growth process in plants, flowers, and insects, and the behavior of rapid-action chemicals, machines, and forces can be instantly clarified by the quickened or retarded eye of the camera. Further, animated moving pictures can illustrate fully and impart the concept and insight into important theories, principles, and processes entirely hidden from even the eye of the camera which can only record overt action of the object or subject.

The instructional moving picture possesses nearly all the advantages of a field trip. The learning experience is made real because it is a reproduction of the actual machine, plant, animal, or process. According to the writer's experience, the motivation and

enthusiasm invoked by a moving picture is equal to, if not more vigorous than, that precipitated by a field trip.

Rooms and Equipment. Every modern science room should be equipped with a portable screen and facilities which will effect complete darkening of the room with considerable rapidity. It is preferable to have each room equipped for moving pictures rather than to have a specialized projection room. This avoids the disturbance created in moving a class from room to room and avoids conflict with other classes. A satisfactory plan is to have a sound projector and a movable screen for the science department so that this equipment can be readily moved from room to room as it is needed.

Pupils can be easily trained to operate the projection equipment efficiently. It has been found effective to organize a permanent group of well-trained pupils under the head of "Movie Crew," or some other suitable name, whose duty it is to take care of and operate the moving picture equipment. This committee may be composed of from five to 10 well-trained pupils who are inducted into the work gradually. This gradual induction serves to maintain a well-trained crew of operators at all times. This crew of operators should have a faculty sponsor whose responsibility it is to supervise the use of the equipment. The teacher should be free from the operation of the machine so that he may supervise other factors about the room. Every teacher, however, should know how to operate a moving picture projector in case of an emergency.

Source of Films. The most desirable arrangement is for the school system or for individual schools, in case they have a large enough enrollment, to maintain their own film library. The county film library may be used efficiently, or several of the school districts or schools may coöperate in the presentation and distribution of films. Where ownership of films is impracticable, nearly every state maintains a film service which contains an ample supply of good silent and sound films in the science field. Other sources of films are available which are under instructional or private operation.[6]

[6] Douglas D. Rothacker, 729 Seventh Avenue, New York City. Erpi Picture Consultants, Inc., 250 West 57th St., New York City. (This company will give list of distributors.) Individual state and national Forestry Conservation Service.

Nearly every state department, state university, and department of agriculture has a film service.

Educational films generally are available at a rate from $.75 to $1.25 per reel per day of use. Silent films usually rent at a lower price than sound films. Commercial and government films are available for the cost of shipment. Commercial films may be secured at the rental price plus the cost of return postage.

Ordering of Films. It is necessary definitely to plan the course in science for at least one semester in advance. If this is done, films can generally be secured at the time at which they are desired, if a semester's or a year's order is placed in advance. The average unit in science continues for approximately two weeks; hence, a leeway of two weeks in the date for which the film is desired should be provided. This plan results in almost full receipt at the proper time of all films ordered. Shortly after the semester order has been placed, the Film Service Bureau will return the statement of the entire semester order, giving dates when the films will arrive. This makes it possible for the teacher to make whatever adjustments are necessary for efficient use of these films. Economy in postage may be effected by ordering at least two related, 15-minute reels to be shown on the same date.

Showing of Films. A day or so before the film or films are due to arrive, the teacher should notify the chairman of the movie operators that the film is coming, stating the number of reels, whether they are silent or sound, and the room in which the films are to be shown. When the day arrives, the operators will be on hand with the film and projector placed in the room in readiness for the showing. New films which have not previously been witnessed by the teacher should be viewed or previewed before they are presented to the class. In such a case, the operators should be notified that such a preview is desired, and it can generally be done after school on the day preceding the showing in the classroom.

Authorities agree, and reflective thinking on the matter reveals, that the optimum procedure is to show a film as a preview of the unit to be studied, then show the whole film, or parts of it, during the Assimilation period of the unit as many times as are necessary for the pupils to master its content, and then, finally, show the film

as a summary of the unit. Such a plan would necessitate keeping a film for the entire duration of the unit, or having the film returned at these additional times. This procedure is possible only where schools or smaller areas have their own film library; but where films must be secured from the state film service this plan is not feasible.

Satisfactory results can be achieved by securing the film only once during the unit. The film should be secured during the Assimilation period, and the pupils should be given a thorough background in the subject matter covered in the film to secure the greatest benefit from the showing. After the film has been presented, a thorough discussion should be employed to clear up difficulties and clinch vital parts. If time permits, and if the situation warrants it, the film may be shown a second time and followed by discussion, either during the same period or at the next meeting of the class. The materials taught by the films should be reviewed from time to time and included in the unit mastery test.

Notices of coming films should be posted at some place where any teacher who is interested can make use of the film in any particular class where it may be of value. Other classes which may use science films profitably are those in manual arts, music, and commercial geography.

Permanent Rating Records. In order to facilitate and improve the selection of films for instructional purposes, a rating record may be made and kept on each film. This record may be placed on a 4 × 6-inch card on which the following information is found: name of the film, source of supply, whether it is a silent or a sound film, cost, and a rating on a basis of a scale of five points as to its suitability for subject fields and grade levels. A copy of the rating card is given herewith.

Method of Financing. The cost of a film program should be paid by the board of education. A comprehensive film program for the science department in a high school of approximately 1,000 to 1,500 pupils can be secured for about $50 to $100 a semester. Under conditions where the board of education is reluctant to furnish this money, the source of income can be developed through science club activities or projects which are sponsored by the science department.

Scientific Films

Unit..............................
Silent..............................
Sound..............................

1. Title..

....

2. No. of reels........................3. Cost per reel........................4. Total cost..................
5. Source of supply..

....

6. Rating of film..
7. Remarks...

Ranking (rank of *1* highest)

Subject	1	2	3	4	5
Gen. Science					
Chemistry					
Physics					
Biology					
Soc. Science					
Com. Geog.					
Literature					
Music					
Others					

SLIDES

Slides are very effective as a teaching aid although they may not be as dynamic as a moving picture. One of the principal advantages of a slide is that it focuses the attention of a class on the subject at hand. It is also true, as was mentioned in the previous discussion, that "a picture is worth ten thousand words." Teachers may prepare their own slides whenever possible.

Method of Using Slides. Slides may be used in practically the same manner as moving pictures. It is more often true that a school or school system has its own supply of slides because in general the cost is less than for movie films. Also, the slide projector costs a great deal less.

Slides may be very effectively employed during the presentation or introduction to a unit. It makes the story of the unit more

significant when the pictures can be viewed along with the story regarding them. During the Assimilation period, slides can be injected wherever more efficient teaching is possible through their use. A type of testing may be done by the use of slides if the slides are placed on the screen and the pupils are required to tell the stories connected with them. With homemade slide equipment which can be purchased along with a slide projector, the teacher of biology, general science, and physics can draw diagrams on these slides, flash them on the screen, and require pupils to identify numbered parts of the diagram. These slides can be kept from year to year if so desired. Slides prepared by the pupil are frequently effective and serve as excellent projects for pupils who have interests and aptitudes in this type of activity.

Source of Slides. Slides in any science subject can be secured from the majority of the sources which distribute films. Generally, higher institutions have an ample supply of slides in the science subjects, especially geography, geology, and biology, and it has been the experience of the writer that these institutions are very coöperative in permitting the use of these slides, providing they have the transportation facilities.

RADIO

A radio can be a very effective supplementary avenue for science teaching if used properly. One disadvantage in a departmentalized secondary school is that the science programs may not be scheduled on the radio at the meeting hour of the class in which it is desired for use. In the nondepartmentalized elementary school, this objection does not hold.

Method of Using the Radio. The use of the radio for the purpose of teaching science may be in any one or all of three forms: 1. Listening as a part of a lesson directly in the classroom. 2. Outside of school listening as part of the regular class assignment. 3. Voluntary listening. In the secondary school science program, as mentioned before, it is only occasionally that listening in a classroom is possible because of the conflict of time. Assigned listening and suggested listening may be very helpful in broadening the child's information about science. Many excellent programs available over both national chains, and very often local broadcasts in nearly all fields of science, are very helpful. Some of the most com-

mon science programs are entitled, "Things that Came True," "Science in the News," and there are many others. Teachers may secure a monthly schedule of science broadcasts from the National Broadcasting Company and Columbia Broadcasting System, and these productions should be utilized because they are too valuable to pass up.

At the present time, the majority of these broadcasts are available in recorded form, and may be used effectively in phonographic reproduction. A combination orthophonic phonograph and radio in a very compact portable form is now available for school use. Where broadcasting stations are not too far away, no aerial is necessary for good reception. Where reception is poor, it is necessary to install an outside aerial which preferably should be a combination aerial that may be extended into two or three rooms.

MODELS

Models are very effective in teaching certain concepts and principles in science. A new development has been "modelograms." Modelograms can be rented from certain libraries or museums for school use at a very low cost. Pupils often can build their own modelograms which frequently are excellent.

Models may be purchased from nearly any company which supplies scientific equipment. Some of the things for which models may be used are to illustrate the size of a liter, or 1,000 cubic centimeters, steam engines, gasoline engines, different types of pumps, structure of the atom and molecule, and the like.

With the use of models, many concepts which are difficult to present with pictures, diagrams, or discussion can be readily taught.

CHARTS AND DIAGRAMS

Charts and diagrams are very helpful in presenting certain relationships and continuity in various phases of science. Some of the common illustrations are charts showing the process of petroleum refining, soapmaking, corn products, cereal products, iron products, alloys, transformation of energy, and automobile manufacture.

The charts on the majority of these subjects may be secured from commercial agencies or institutions such as "The American

Institute of Soap-Making," "Forestry Production Laboratories," "American Association of Oil Refineries," and individual corporations. In the use of these charts, it is wise to determine whether or not undesirable advertising is found. For instance, it would be unwise to display a chart on the manufacture of the Chevrolet automobile and not have charts on other cars in a similar price range. This would be unfair advertising for the other automobile dealers in the community. Charts which advertise nationally known products that are sold by practically every merchant need not possess this objection. For example, a chart on the manufacture of Palmolive Soap would not be unfair to any grocery merchant because every grocery store handles this article.

A science teacher should attempt to secure as many of these charts and diagrams as possible. It is often worth-while to buy these from commercial science supply companies. These contain no advertising and, in general, would be of better quality and more accurate than those distributed free by commercial agencies. Pupils can often prepare diagrams and charts which may be kept and placed on display. Charts should be displayed in a convenient place in the classroom or laboratory where pupils have an opportunity to browse around and study them. These charts should be changed frequently so that the display becomes dynamic. It is comparatively ineffective to permit a chart to hang on the same place on the wall month after month and year after year.

EXHIBITS

Every science room should have facilities for the exhibition of materials and products which are of scientific value. Downtown exhibits, at the Fair, automobile show, and the sport show may be effectively utilized by the teacher as a means of imparting scientific information. Exhibits prepared and presented by the science class or science club may be effective in teaching scientific information to other pupils of the school and parents who are not formally studying science. It is often possible to secure exhibits which have been used for commercial purposes for exhibition in the school for a certain period of time. Many of these exhibits may be secured as donations after they have served their purpose commercially. Such acquirements are valuable additions to the supply of objective aids.

WORKBOOKS

Workbooks are a commercial product which has resulted from the introduction of the unit plan, and fulfill a definite need. These workbooks provide effective and efficient study guides for pupils while they are working independently during the Assimilation period. If used correctly, more efficient teaching may be done by using this type of teaching aid. These workbooks are prepared by teachers who have had a great deal of experience in the field of teaching the science subject for which the books are prepared, and they are an effective aid to the teacher who is using them.

The suggested activities and projects included in the workbook in general are much superior to those which can be suggested and developed by the busy teacher in the field. The use of a workbook does not necessarily mean that the teacher should not supplement it with his own ideas and suggestions as to activities and projects. It is desirable that the teacher do this. Generally, the average teacher, especially the beginning teacher, is so overloaded with the regular routine of teaching that he has little time to devote to the preparation of study outlines and projects. As a result, the teaching degenerates into mere lesson studying and lesson hearing which requires very little preparation outside of class.

The use of workbooks has a few objections, but it is the opinion of the writer that it is not the workbooks, in general, that are at fault, but the improper use of them. One point which must be watched: the teacher should not lean too heavily upon the workbook. This makes the activities stereotyped and without motivation. Many teachers who do not use workbooks properly tend to put pupils to work on the workbooks and then go about doing something else—visit with some other teacher, leave the room, and pursue other undesirable practices. The workbook is intended to be an aid to more effective supervised study; therefore, the principles for the conduct of the supervised study period should be utilized. This means that the teacher should be just as busily occupied while the pupils are working on these workbooks as when he is guiding class discussion. The teacher should move about the class and make constant observations and suggestions, and help the pupils whenever necessary.

A second objection to the workbook is the cost involved. Ordinarily, the pupils are asked to pay for their workbooks so that they may use them as they prefer. Pupils may write in them, which makes them more effective. Many boards of education hesitate to spend money for these workbooks for the pupils to use and possibly destroy and mar after they complete them. Although not as desirable as the previous method, one way is to use the workbook as a guide for study, and not permit the pupils to write in them. In this manner, the books may be used by many successive classes until they become worn out.

While workbooks are being used in these science subjects it is necessary to vitalize the class work with discussion, oral reports by the pupils, supplementary activities suggested in the workbook, and appropriate projects which may be suggested by the teacher or pupils. Pupils should be required to write complete sentences and take pains to write with conscious care in the workbooks so that undesirable and careless habits are not developed.

THE BULLETIN BOARD. The science bulletin board may serve as an effective teaching aid in at least three ways. First, it provides vitalized materials which supplement other sources of information, and secondly, the bulletin board may be used as an effective motivation device. A third value which many educators consider more important than the other two functions is the opportunity for utilizing the bulletin board as a project for developing creativeness, responsibility, and other abilities in many pupils. Every science room should have ample bulletin board space covering at least half the available wall space. In most science rooms too much space is devoted to blackboards and not enough to bulletin boards.

Bulletin board materials may be developed by the pupils and the teacher. A large number of pupils in every class get a great deal of satisfaction from finding pictures, diagrams, and write-ups, on the current unit under study in science. These materials may be mounted attractively and securely so that they can be filed away for future use should the pupils not care to keep them for themselves after the unit is completed. The teacher should also assemble materials for the bulletin board. It has been the writer's experience, however, that the pupils can provide more than is practicable

for effective use. Pupils find bulletin boards very interesting and spend a great deal of time studying them if they are kept up to date and alive. As much time as possible should be allowed for pupils to study these materials: before classes begin in the morning, at noon, and after school, and during the directed study period. It is often more profitable for certain pupils to study the bulletin board while the rest of the class is having a discussion period.

A large portion of the space should be utilized for exhibiting work done by the pupils. Drawings, written reports, and paintings which have been prepared by the pupils make splendid material from an educative point of view for the rest of the class and pupils who prepare them. Posting these achievements whether they be excellent or mediocre, providing they are the best efforts of the pupil, serves as a very strong motivating force. It encourages greater participation on the part of the whole class in this type of activity as well as stimulates the contributors to do more of it and achieve improvement. No school subject affords greater opportunity for developing creative ability in the pupils than science at all levels.

Maximum value is derived from the use of the bulletin board when pupils take charge of it with the counsel of the teacher. Pupil committees take a great deal of interest in this activity and derive an inestimable educational value from it. It gives them an opportunity to exhibit and develop their creative ability in preparing an attractive display. This ability involves sense of proportion in the areas of space, color, concentration, classification, and many others. Choice of committees should be on the voluntary basis. If a large number of pupils express their desire to care for the bulletin board, many committees may be formed and time for each limited so as to give all an opportunity to profit from the activity. Pupils who have charge of the bulletin board usually solicit contributions for the display from the pupils in the class during the directed study period or at other convenient times. All the committee work can be done during the study period rather than require that it be done outside of class. This plan tends to make for more satisfactory results. Continuous contribution on the part of the pupils tends to keep the bulletin board dynamic. Often some change is necessary each day to make room for contributions.

Microprojection. A need which has been felt for a long time by science teachers, especially those in biology, is microprojection. It is now a realization and is available at a price which almost any school can afford. One microprojector can effectively replace the microscope in general science and to a large extent in high school biology. Not only does it save a great deal of money for the science departments, but greatly increases the efficiency of teaching. If individual microscopes are used it is difficult for teachers to ascertain whether the pupils see what they are supposed to, and a great deal of time is wasted in adjusting the vision. With a microprojector the attention of the whole class can be focused upon the image on the screen while vital parts of the enlarged object are discussed and critically observed. In high school biology adequate learning is achieved from group observation and discussion of microscopic slides. Representative drawings are not easily made with the microprojector, but from an educational point of view, the value of this activity is seriously questioned for all pupils.[7] It may be justifiable to let pupils who desire to draw, do so.

It is not the intention to recommend that good instruction in high school biology can be attained with the microprojector and only one microscope which goes with it. It is desirable to have from three to six microscopes of moderate quality so that pupils can make individual observations and investigations. The microscope which is to be used with the projector should be of a high quality. This can be afforded when the number of microscopes can be so materially reduced.

STUDY QUESTIONS

1. What arguments can be given for using moving pictures as a teaching aid?
2. How may moving pictures be employed to replace field trips?
3. Give the results of experiments on the efficiency of moving pictures as an instructional aid.
4. What type of rooms and equipment are necessary for effective use of moving pictures and slides?
5. Give several sources of classroom films in order of utility.
6. Describe a procedure in ordering films.
7. Give three places during a unit when films may be effectively used.
8. Describe the procedure which should be followed in using films most effectively.

[7] See p. 179.

9. How may an effective record be kept which includes a rating of the efficiency of the film?
10. How may a film program be financed?
11. Discuss the procedure in the use of slides.
12. Describe an effective procedure in the use of the radio for science teaching.
13. How may models, charts and diagrams, and exhibits be utilized in more effective teaching?

ADDITIONAL PROBLEMS AND PROJECTS

1. Select a reliable reference on the evaluation of moving pictures and give a report to the class on the findings.
2. Demonstrate the use of slides and models before the class.

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16

Science Rooms and Equipment

In order to effect efficient science teaching, it is necessary to use specialized rooms and equipment. There is considerable disagreement as to the form of both of these phases but, in a minor way, practice has produced a certain amount of standardization. The type of rooms and equipment which are desirable depend upon the size of the school and the number of pupils studying science. There are differences also according to the type of science which is taught. An attempt will be made to give a survey of the best practice at the present time.

SCIENCE ROOMS

Theoretically, there should be no differentiation between the recitation room and the laboratory room for the classes in science subjects because laboratory activities and experiments should be injected at any moment when it is necessary. Separate recitation and laboratory rooms make it necessary to schedule certain days for their use. From an economic point of view, it is desirable to have separate recitation and laboratory rooms, because to provide every science recitation room with laboratory facilities involves more expense than the majority of school administrators feel is justified.

Chemistry. For schools ranging in size from 100 to 500 pupils the chemistry room should be a combination of recitation room and laboratory. The room should be of unusual size, at least 22 $\times$ 40 feet, which makes allowance for chairs in the front of the room for purposes of discussion, and laboratory desks in the back of the room. With the use of the unit plan, and with most of the time spent in directed study, the chairs in the front of the room may not be necessary. In such a case, the laboratory tables should be provided with seating facilities which are comfortable for sitting and for writing while being seated. At the present time such desks are available from suppliers of school furniture.

Every chemistry room may be provided with a supplementary supply room. In many states it is required that this chemistry supply room be placed outside the school building because of the fire hazard involved. This is generally taken care of by building a small room projecting out from the regular building with a fireproof door. Before plans are made for construction of the building in which chemistry is to be taught, it is advisable to investigate the state law applying to such buildings.

THE PHYSICS ROOM. Under practically all conditions physics rooms may be on the combined recitation and laboratory plan. Ordinarily, four-pupil tables are quite adequate for directed study, discussion, and experimentation. These tables may be connected with gas and electricity. If it is undesirable to make these connections at the tables, it may be satisfactorily taken care of by providing a large table or tables around the room to which these connections are made.

In small schools, it is frequently necessary to combine the physics and the chemistry classrooms and laboratories. This may be done quite satisfactorily. In the physics room there should be a demonstration desk which has water, electricity, and gas connections. The physics room should have an ample supply of instrument and equipment cases with glass doors which can be securely locked at all times. The glass doors permit display of equipment. It is found that pupils learn a great deal and develop much interest in physics by having opportunity to observe pieces of equipment without handling them.

BIOLOGY ROOM. The biology room should be equipped with a demonstration desk which has water and gas connections. The remaining desks for the pupils may be two- or four-pupil tables. These tables need not necessarily be connected with water, gas, or electricity. One or two tables with such connections may be desirable. A southern exposure is good for a biology room, or an eastern exposure with possibly a projection providing for a greenhouse which should be glass covered and, if possible, have a southern exposure. An ample supply of glass cases should be available for the purpose of display of mounted specimens of different kinds.

GENERAL SCIENCE ROOM. The general science room may be a room of standard size, with at least one blackboard in front of the

room for demonstration purposes; one good-sized equipment case, preferably close to the front of the room; and tables or benches around the sides of the room, some of which may be used for the growing of plants and aquaria, and others for the purpose of experimentation where gas, water, and electricity are needed. There should be a standard general science demonstration desk in the front of the room and two-pupil tables for the pupils. These tables are desirable because they provide for a socialized environment and make it possible for pupils to do experimentation at these tables. Individual desks are undesirable because generally the surface of these desks is too small for effective experimentation should there be the desire to do so.

EQUIPMENT

It is very important to provide adequate and proper equipment for each of the science courses. Each of the four courses, namely, general science, chemistry, physics, and biology, needs separate types of equipment. No attempt will be made to discuss these sets of equipment in detail, but a reference list of each type of equipment will be found in the Appendix.[1] Generally, each laboratory manual gives an adequate list of equipment and supplies which are necessary for the efficient conduct of classes in these subjects.

There is some controversy concerning the efficiency of pupil-made equipment as compared with factory-made science equipment. The experience of the writer and other science teachers has been that factory-made science equipment is more efficient in the long run. Pupil-made equipment tends to be less accurate, less durable, and of little value except to the pupil who makes it. Even for the pupil who makes the piece of equipment, the scientific principle involved tends to be lost in the activity. If financial difficulties make it impossible to purchase ready-made equipment, pupil- or teacher-made equipment may serve temporarily until adequate finances can be secured.

Perpetual Inventory. A perpetual inventory should be kept for all equipment and supplies. When once set up, this type of accounting may be kept up to date with facility and save the science teacher a great deal of time. This inventory makes available at any

[1] See p. 260.

time the amount of supplies and equipment on hand. Especially prepared 4 × 6-inch cards may be conveniently used for this purpose. One card is employed for each item of equipment and supplies. These cards are alphabetically filed in a suitable permanent file. As soon as a jar or bottle of supplies is emptied a record is made on the card and the balance on hand is indicated. The same type of record is made for the items of equipment. At the end of the year when new supplies and equipment are to be ordered, the inventory may be referred to and the order can be made out in the minimum amount of time and omissions as well as overstocking of certain items are reduced to a minimum.

GENERAL SPECIFICATIONS

Projection Rooms. Every science room should be equipped for effective use of visual aids. Opaque curtains which can make the room dark enough for opaque projection are necessary for satisfactory instruction by this means. One portable movie screen may be adequate for the science department in a building and one of each of the following pieces of projection equipment: 16 mm. sound movie projector, opaque projector, and slide projector separately or combined with the opaque projector.

Darkroom. One darkroom for the whole science department is sufficient to take care of all science subjects taught in a single building unless it houses over 2,000 pupils. This darkroom may be most functional if placed in connection with the physics room because the pupils studying physics generally make most use of it in connection with the study of photography. Chemistry and general science pupils will find this adequate for their occasional demands for such facilities.

A darkroom should be large enough to accommodate from eight to twelve pupils at a time. In order to do this, the dimensions required are approximately 8 × 12 feet with a small vestibule at the entrance to keep out light while going in and out. Increased efficiency of the room may be effected by installing two sinks and running water, one at each end of a long table which should be placed in the center of the room so that both sides are available for work space. Along the sides of the room may be the tables or benches to be utilized for experiments by pupils in the biology and general

science departments in the area of growing plants, etc. This space may also be utilized as additional work space. Above the benches may be shelves for the purpose of storing pans, necessary equipment, and supplies which are frequently used. Ample drawer space also is desirable. Electrical outlets should be plentiful so that enlarging equipment, slide-making equipment, and lights can be readily connected. In large schools it may be better to have two smaller rooms so that one may be used by the more advanced pupils.

Location of Science Rooms. From the point of view of teaching efficiency, economy, and convenience it is desirable to have all the science rooms concentrated in one section of the building, preferably on one floor. If possible, a single wing of the building should be utilized because greater width of the room—from 24 to 28 feet—is found to provide for more functional space. As the standard width of school rooms is 22 or 23 feet it can readily be seen that economy can be effected if only one wing of the building must have this extra width.

Flexibility. In both large and small school systems it has been found more economical to have a maximum amount of flexibility in the plans of science rooms. Science rooms should be constructed and equipped so that activities other than those relating to science may be conveniently conducted in them. Each room regardless of the size of the school is used for a home room and in smaller schools almost any other subject may be taught with reasonable comfort to the pupils and teacher. Tables of the T type for physics and chemistry have been found to satisfy this requirement. Some have utilized the disappearing sinks and faucets with great success. With this type of equipment all science subjects can be taught in a single room. Instead of the separate store and supply rooms for science subjects a generous supply of cabinets in the room has been found to be more convenient as well as more economical.

STUDY QUESTIONS

1. Describe the furniture and equipment which are desirable for a general science room, a biology room, a physics room, and a chemistry room.
2. In a small school, which subjects may be most conveniently taught in the same room?
3. Under what conditions is it most desirable to have a combination recitation room and laboratory for chemistry?

4. How does the efficiency of pupil-made equipment compare, in general, with factory-made equipment as far as the objectives of science teaching are concerned?
5. Where would one find a list of the apparatus, equipment, and supplies necessary for each one of the science subjects?

ADDITIONAL PROBLEMS AND PROJECTS

1. Make drawings of the science rooms, including furniture, for at least two science subjects of your choice.
2. Make a complete list of equipment and supplies necessary for teaching a satisfactory course in one science subject.
3. Secure a catalog and order blank and make a complete order, including costs, code numbers, etc.

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17

Guidance and the Science Teacher

The science teacher may be very helpful in both the educational and vocational guidance of the pupils under his direction. The modern concept of guidance is that the classroom teacher is the crux of any guidance program. The teacher should be on the alert to watch for special aptitudes in each and every pupil so that these aptitudes may be discovered and developed to their fullest extent.

The frequently made statement that "there is a spark of genius in every child" has its limitations and we know that it is not actually true. We do know that there are certain special abilities which we consider on the level of genius. Nearly all pupils who are capable of executing the activities required in the present secondary school, if they have an I.Q. of 80 or above, have a special ability which is adequate for ordinary competition in whatever field it may be. This means that every child, if his special ability is discovered, will be able to earn an adequate living in the area in which he has ability.

GUIDANCE IN THE SCIENCE CLASSROOM

The science teacher has an exceptional opportunity to observe the pupils in all phases of ability, namely, the intellectual, artistic, manual, mechanical, social, and creative. In providing a variety of activities which are possible during the Assimilation period in a unit in any one of the sciences, the teacher can watch for special abilities which may be indicated. If such special abilities are observed, the teacher should make recommendations to the child so that he may modify his program if possible, and especially encourage a child in the special ability so that he may secure enough enthusiasm and momentum to continue in its development. Many persons who have achieved outstanding success in specialized fields can relate an incident where some kind and understanding teacher encouraged them to go on with study in this area.

During the Assimilation period of a well-guided unit in any secondary school science subject, pupils have an opportunity to explore and develop their abilities in elementary library research, skill in experimentation, drawing of the plane and perspective type, freehand drawing, color sense, leadership, oral and written expression, mechanical aptitude, finger dexterity, social adaptation, and many others. This may be accomplished by providing for enriched pupil-purposing experiences such as free reading, committee and individual projects pursued in and out of school, and pupil oral and written reports pertinent to the problem or unit approved for class study.

In order that a science teacher may execute this guiding phase effectively, all science subjects in the secondary school should be taught with the idea of exploration. At the present time a child is rarely able to secure a position in the science field immediately after leaving high school. With this fact in view, it is evident that a high school's main objective is, not to prepare chemists, biologists, and physicists, but to give pupils a background with which they may interpret their environment, secure better living, and have revealed to them the possibilities of future study in these areas of science.

In connection with the teaching of the science subjects, pupils should be encouraged to study and report upon the life histories of famous scientists. These biographies may reveal to the pupils the training necessary and the experience and abilities required for success in the science fields. Along with this, the pupils should be encouraged to read and study about different scientific professions, such as medicine, all types of engineering, medical technology, and nursing.

SCIENCE CLUBS AND GUIDANCE

The science teacher has unlimited possibilities in effecting educational and vocational guidance through the activities of science clubs. In order to secure the maximum amount of guidance, especially in the larger schools, the activities for each club should be comparatively narrow in scope. Science clubs are functional in the junior high school, but in the senior high school specialized clubs are preferable and should be confined primarily to activities re-

lated to chemistry, radio, physics, biology, or health, and may be named accordingly.

The guidance objective in these club activities may be achieved through (1) activities within the school, and (2) field trips. At the regular club meetings the members may engage in advanced experimentation and reading, and they may conduct discussions concerning occupations and professions requiring a scientific background. During field trips the members are given the opportunity of seeing the chemist, engineer, medical technician, x-ray technician, and laboratory worker actually at work.

Pupils in cities of 20,000 or more have the advantage of these first-hand observations in their own community where field trips can be conducted during school time or after school without interference with regular routines. Schools in smaller communities, however, have these facilities within a maximum radius of 75 miles. With present transportation facilities, such distances are not a handicap. During a single day, from three to five establishments may be visited and outstanding educational and vocational guidance values achieved. Missing a day of school for such purposes has no more objectionable features than losses due to the activities of interscholastic athletics.

The city health department, a modern clinic, and a hospital with its modern medical and x-ray laboratories provide excellent guidance opportunities for prospective medical technicians, nurses, and students of medicine and medical research. Any factory, foundry, brewery, or sewage disposal plant which is of sufficient size to maintain a full-time chemist and laboratory can make the responsibilities of the engineer, chemist, and so on more real to the inquiring pupil.

The science teacher has a greater opportunity than the teacher of other subjects in the secondary school to give functional educational and vocational guidance. A teacher is not fulfilling his mission if these opportunities are neglected.

EVERY TEACHER A GUIDANCE WORKER

Education today requires a far more effective, versatile, dynamic, vigorous, and human teacher than did the schools of 50 years ago when they were merely of the fact-imparting type. To-

day, the complexity of the social environment necessitates increased skills, habits, information, and abilities for successful social life. The change in the tempo of our social life, technological developments of recent years, the introduction of new and challenging social problems, and the increased international contacts and difficulties increase the necessity for more effective teachers. Today, the teacher must know a great deal more about a greater variety of subjects and, at the same time, be able to stimulate specialized interests and guide them. Our knowledge of pupils and our interest in them has greatly increased during recent years, and a successful teacher must have a complete working knowledge of the complex human being. An efficient teacher today must be a student of pupils as well as a student of subject matter. In a great measure the problem now is that of assisting a complex and unique individual pupil to make a continually successful adjustment in a complex social order.

The teacher of today must be an educational scientist. He should be capable of analyzing and evaluating new teaching methods, of carrying on classroom experiments, and of continually seeking new educational materials. This type of activity necessitates the understanding of research methods, educational statistics, and a scientific vocabulary. Teacher growth is equally as important as pupil growth. The increased democratization of administration makes it necessary that teachers be more highly trained and competent because of increased breadth of knowledge of the many areas involved in the process of educating. They must also possess a greater insight into the proper development of the whole child than was possessed by the average teacher in the past.

An effective learning situation is seldom possible until the teacher is intimately acquainted with the pupils. Because of this, a teacher's responsibility is to become as well acquainted with these children as present methods make possible. He should become interested in acquiring new and more effective techniques for learning about the pupils. Such techniques may be records, reports, observations, tests, inventories, individual conferences, group activities, standardized instruments, autobiographies, pupil reactions, and parental contacts. It is difficult for the teacher to adapt his work to the individuals in his class or to stimulate pupils effec-

tively until the backgrounds, interests, needs, and abilities of his pupils have been determined.

Responsibility for the whole development of the pupils stimulates the teacher and makes possible better coördination of all phases of the child's growth. These new guidance responsibilities include their vocational, recreational, social, educational, moral, physical, and emotional needs. A teacher tends to see the place and value of subject matter, the need for change, and the importance of effective guidance. As a result, a new insight into the whole educational process is acquired. The guidance program can provide new and stimulating problems for teachers to solve. As children grow gradually by assuming and taking care of new responsibilities, teachers similarly grow on their level of activity. This growth necessarily must be evolutionary rather than revolutionary.

HOME ROOM GUIDANCE

The responsibility of directing the activities of a home room becomes the opportunity of practically every teacher. The responsibility for effectively guiding pupils is not, and cannot be, entirely centered in a home room, but it has been found through experience that there will be more effective execution of these responsibilities if localized in a certain place, such as the home room. Because every teacher, regardless of the subject matter area for which he is trained, will be expected to take charge of a home room, training in this area is necessary.

Need for the Home Room. The need for the home room type of organization in our junior and senior high schools has grown out of two broad developments: (1) Abandonment of Faculty Psychology. (2) Departmentalization.

The new psychology demands ministration to the individual pupil, because through years of experimentation and study it has been revealed that there is a great spread of individual differences with respect to capacities and interests. The accumulation of experimental data which tended to disprove the theory of mental discipline revealed the inadequacy of "mental calisthenics" as a preparation for life. The previously accepted theory of training of the faculties, such as memorization or reasoning, in one area, was found to be practically ineffectual when transfer was attempted

to other areas; hence, it is concluded that training must be more or less specific. It is still believed, and there is some experimental evidence to substantiate the thesis, that certain abilities may be transferable to other areas. Among such abilities may be included the use of the scientific method and scientific attitude, and certain character traits such as persistence, industry, honesty, and the like. The conviction of the necessity for specific training resulted in the development of differentiated curricula. These have, in many large school systems and secondary schools, differentiated and developed into dozens of courses of study and hundreds of subjects. In addition to the increased complexity of the program of studies in the secondary schools, progressive society has developed in the neighborhood of 20,000 different jobs for which a pupil may train. A situation such as this complicates the wise planning of the immature child. It becomes mandatory that some type of educational vocational guidance be provided.

A generation ago, when the Faculty Psychology was in vogue, and when all educational problems were solved by the laborious study of Greek, Latin, higher mathematics, and systematized science and history, the problem of choosing a course of study was simple because there was only one provided; and when it was believed that this one type of training was a good fundamental preparation for any vocation, no thought was necessary regarding a vocation until the time presented itself. This is not the situation today.

Departmentalization. The increased amount of information which educators feel should be handed down to the future generations has become so voluminous that specialization on the part of teachers is necessary This specialization naturally creates a necessity for departmentalization. The sudden change which the pupil undergoes in transferring from the elementary grades to the junior high school where he moves from room to room for each subject disturbs the security of the child because he is left without a "home" and "mother teacher."

In observing the emotional and psychological make-up of adults, it is discovered that they, too, have a need for a socially secure home. This is evidenced by the development and maintenance of fraternities, sororities, lodges, and other social groups which are

prevalent in society. The home room tends to satisfy this need by providing a room and teacher to whom the pupil goes regularly each day and where he finds fellow pupils with whom intimate acquaintance has been developed. This gives the child a very much needed sense of security which is essential to his happiness and normal development. Without a home room, orientation to the school community is difficult because in such a new and complex situation the child has no close friend to guide him.

Functions of the Home Room. The home room organization has two functions: orientation, and educational and vocational guidance.

Pupils need help in adjusting to the new school environment. Here they find new teachers, new subjects, and new regulations. The home room teacher can be of help in orienting the child to this new situation. It is impossible for the principal to be of much help in this because he is too remote and has too many pupils for the administering of adequate individual attention. Pupils need social guidance which involves the making of friends, coöperation in the school community activities, and the like. Personal growth is an additional area in which the teacher can be of great help to the child. This involves guidance in dress, cleanliness, and manners.

Educational and vocational guidance can be exercised effectively in the home room. The home room teacher should know more about the pupils under his care than any other individual in the school. For this reason, he should be helpful in the selection of subjects, filling out of program cards, and choice of clubs and extracurricular activities. In addition to this educational guidance, the home room should be a place where pupils may secure elementary information regarding vocations. It is not intended that this should replace a comprehensive course in vocations which may be more profitably offered during the junior or senior year of the secondary school. It is generally agreed that during their entire secondary school career, beginning with the seventh grade, pupils should constantly be reminded that it is their responsibility to choose a vocation which they plan to follow as a life work.

Duties of the Home Room Teacher. The duties of the home room teacher are many. His first responsibility is to become intimately acquainted with every home room pupil. This may be ac-

complished by an intensive study of the cumulative record card, conferences with parents and teachers, and close observation of the pupil in the classroom. The home room teacher should know the pupils' abilities, aptitudes, home environment, health condition, economic status, emotional stresses, and ambitions. All these data are not found on cumulative records. The teacher should make a study of each pupil in his home room. This may be done by watching for special aptitudes, interests, emotional disturbances, and health conditions. He should consult and guide pupils in problems involving orientation, discipline, educational and vocational plans.

A second responsibility of the home room teacher is to guide home room activities effectively. A principle which may be helpful in guiding home room activities is that the teacher should be an influential leader behind the scenes. The teacher may find it necessary to take the initiative at first in order to give the pupils enough momentum to carry on their own activities. Pupils, if properly guided, will initiate their own activities and carry them on without very much direct help from the home room teacher. Occasionally, it may be necessary to exercise leadership when ideas seem to be scarce and when problems appear which apparently are too complicated for the youthful minds to solve adequately.

The Nature of Home Room Activities. The home room activities may be of many forms and approaches. Some believe that the home room period should be the pupils' period; that is, the children should be permitted to do what they wish without interference from the home room teacher. This gives the pupils an opportunity to develop and grow in a natural way, to initiate and solve their own problems, and to permit practice in democratic living. This policy is employed in many of our national progressive schools. The second type of activity which should occupy a small portion of the home room time is administrative work in connection with the operation of the school. This includes announcements, selling tickets, taking attendance, discussion of school regulations, and the like. Where home room periods are relatively short, ranging from 10 to 20 minutes, this is about the only type of activity which can be properly done. Consuming the entire home room period with this type of activity, however, is not considered the proper use of the period.

At the beginning of the school year, and especially in schools of 150 pupils or more, orientation activities have a fundamental place in the home room program. This involves getting acquainted with fellow pupils, the building, teachers, and rules and regulations. These orientation activities may be accomplished through home room parties, guide tours through the building, school mixers, and the like. Home room representative participation in the pupil-teacher council tends to make more realistic the discussion and study of rules and regulations which apply to the school community.

Guidance activities should consume a definitely greater proportion of the time devoted to the home room period. Group and individual counseling in all areas of pupil growth should be provided. These areas may include personal problems of the pupil as well as those of an educational and vocational nature. Participation in school government affords guidance and experience in democratic living. The home room representative to the school council has an opportunity to report decisions and findings of the council to his home room and to present to the council the proposals and suggestions of his home room. A study of the different types of curricula offered and the educational program clubs available to the pupils, and vocations from which the pupils may have an opportunity to choose, may take up a considerable portion of the time. Activities which tend to develop patriotism and appreciation of our form of government may be observation of important dates, recognition and observation of weeks dedicated for certain purposes, such as Fire Prevention Week, Health Week, Book Week, and Education Week, and important birthdays and anniversaries. Discussion and formulation of manners and moral codes are effective in developing good character traits in the home room groups.

Duties of officers, *Roberts' Rules of Order,* and appointing and follow-up of the activities of committees are potent in their possibilities of producing growth in the area of citizenship training. A systematic study of "learning how to study" may be of great help in improving the school success of the pupils.

At the present time, there are many publications on the market which are specifically prepared for use in home rooms. It is the opinion of the writer that such prepared materials, if properly

selected, may be the most effective means of assuring significant activities in the home room on the part of the average teacher. The activities suggested in the previous programs may serve to supplement those provided in the commercially prepared materials. The home room teacher and principal should constantly be on the alert, watching for improved prepared materials in the area of home room activities. Materials which are available at the present time may be in the form of workbooks, books patterned after basic texts, and publications which are rich in suggestions for vital home room activities.

STUDY QUESTIONS

1. Evaluate the statement, "There is a spark of genius in every child."
2. In what ways does a science teacher have an opportunity to guide a pupil toward a better school and life adjustment?
3. How may science clubs be utilized in guidance?
4. Give the qualifications necessary for a teacher who is capable of doing what is expected of him in the modern school.
5. What conditions have made the home room a necessity?
6. Name and discuss the main functions of the home room.
7. What are the duties of the home room teacher?
8. List and describe briefly the nature of home room activities.

ADDITIONAL PROBLEMS AND PROJECTS

1. Select three children representing the low, medium, and high ability levels and attempt to determine their life ambitions. Describe the procedures which the teacher may use in helping the child to realize these ambitions, or in helping the child to make a better adjustment.
2. Report to the class or write a comprehensive report on the guidance activities which have been accomplished by science clubs.

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Appendix

Sample of Semiobjective Test:

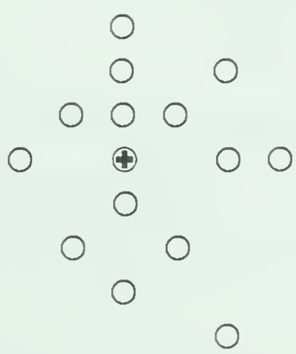
Chemistry I Test—Unit IV

Electrons and Principles of Reaction

I. Identify:

Electron, proton, external electron, outmost ring, va-
30[1] lence, nucleus, atomic number, metal, nonmetal, iron,
2[2] periodic table, complex ion, radical, suffix, prefix.

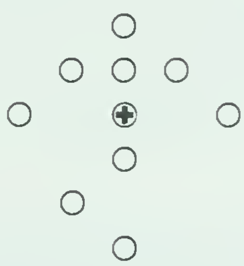
II.



1. Atomic No.?................
2. Valence?.................
3. No. of electrons in outmost ring?.................

10 4. No. of external electrons?................
1

5. No. of complete rings? ....



6. Activity?.................
7. Metal?.................
8. Activity?.................
9. Valence?.................

10. Valence?.................

III. Give the formula and name the compounds formed when the following ions unite:

[1] Value of the question.
[2] Value of each item.

		Ions		Formula	Name
	1.	Na^{+}	Cl^{-}	....	....
	2.	K^{+}	No^{-}	....	....
40	3.	NH_4^{+}	SO_4^{--}	....	....
4	4.	Mg^{++}	OH^{-}	....	....
	5.	Zn^{++}	PO_4^{--}	....	....
	6.	Al^{+++}	SO_3^{--}	....	....
	7.	Mg^{++}	S^{--}	....	....
	8.	Cu^{++}	ClO^{-}	....	....
	9.	Fe^{++}	ClO_3^{-}	....	....
	10.	Ba^{++}	ClO_2^{-}	....	....

IV. Name the following:

10 1. H_2SO_4 6. $HClO_4$
1 2. H_2SO_3 7. Fe^{++}
3. $HClO$ 8. Fe^{+++}
4. HCl 9. Hg^{+}
5. $HClO_3$ 10. Hg^{++}

V. (a) How many grams of ammonium hydroxide and sulfuric acid are used to make 20 g. of ammonium sulfate?
10 (b) How many grams of $MnO_2 + HCl$ are necessary
5 to produce 1000 liters of chlorine? (Density of Cl = 3.21 g. per liter or 1000 cc.)

Chemistry Test

Unit of Halogens

True and False

Please use + for *True* and 0 for *False.*

1. Chlorine is the only halogen found in the human body.
2. The halogens are chlorine, iodine, sodium, and potassium.
3. Halogen means "salt maker."
4. Fluorine is the least common halogen.
5. Fluorine is extremely active.
6. Compounds of all halogens except fluorine are found in sea water.
7. Seaweed (kelp) is an important source of iodine.
8. The halogens resemble chlorine in chemical properties.
9. Iodine is obtained to some extent from Chile saltpeter.

True and False

10. There are few substances which fluorine does not attack.
11. Fluorine is produced by electrolyzing a solution of KF in HF.
12. Fluorine must be produced at a low temperature of 23° C.
13. "Mother liquor" is the liquid remaining when certain salts are crystallized out.
14. A large part of the bromine supply is secured from sea water.
15. There are less than 70 parts of bromine in one million parts of sea water.
16. Bromine is prepared in the laboratory by adding sulfuric acid and manganese dioxide to a bromide and heating gently.
17. The method of preparing iodine is similar to that for bromine.
18. At room temperature, iodine is a liquid.
19. Bromine is a gas at ordinary room temperature.
20. Fluorine is a gas at room temperature.
21. Bromine is insoluble in water.
22. Bromine water is a solution of bromine in alcohol.
23. Bromine is very soluble in both chloroform and carbon tetrachloride.
24. A test for bromine is the orange color formed when bromine dissolves in CS_2.
25. The chemical behavior of bromine is similar to that for chlorine.
26. Tincture of iodine is a solution of iodine in alcohol.
27. Bromine combines with very few substances.
28. Sublimation is the turning from a solid to a gas without going through the liquid stage.
29. Iodine and phosphorus react vigorously to form phosphorus iodide.
30. The halogens have a valence of plus 2.
31. The halogens have electrons in the outmost ring.
32. Bromine will replace chlorine in sodium chloride.
33. Chlorides give off more heat in forming than bromides.
34. Iodine will replace bromine in a compound.
35. The test for iodine is the violet color when CS_2 is added to an iodide to which chlorine water has been added.
36. If an iodide and a bromide are present, special care in adding chlorine will oxidize the iodine color, leaving the bromine color in the halogen test.

True and False

37. Hydrogen compounds of the halogens are bases.
38. Hydrofluoric acid etches glass.
39. Hydrofluoric acid is stored in glass bottles.
40. In etching glass with HF, wax is used.
41. Soluble fluorides are sometimes used as insecticides.
42. Hydriodic acid has many common uses.
43. Many iodide salts are used in medicine, photography, and dye-making.
44. Hydrogen bromide is less stable than hydrogen iodide.
45. Hydriodic acid is unstable.
46. SO_2 is produced when H_2SO_4 is added to KBr.
47. Hydrogen sulfide is formed when sulfuric acid is added to potassium iodide.
48. Bromides are more stable than iodides.

Multiple Choice (1 point each)

Place the number of the correct answer in the space provided at the right.

1. Sulfuric acid is not used in the preparation of ....
   (1) bromine, (2) fluorine, (3) chlorine, (4) iodine
2. Bromine in a bromide solution will be displaced by ....
   (1) chlorine, (2) sublimation, (3) iodine, (4) carbon bisulfide
3. The color of the solution of iodine in carbon disulfide is ....
   (1) yellow, (2) amber, (3) purple, (4) colorless
4. Bromides are used in making ....
   (1) explosives, (2) motion pictures, (3) automobiles, (4) fertilizers
5. The most active of the halogens is ....
   (1) bromine, (2) iodine, (3) fluorine, (4) chlorine
6. Bromine in water is ....
   (1) very soluble, (2) fairly soluble, (3) insoluble
7. The state of iodine at room temperature is a ....
   (1) liquid, (2) solid, (3) gas
8. Bromine compared to water is ....
   (1) heavier than, (2) lighter than, (3) the same weight as
9. A little chlorine water was added to a solution of an unknown halogen salt, which turned a light yellow-brown color. A little

CS_2 was then added, which turned a violet color. The unknown salt was ....
(1) an iodide, (2) a chlorine, (3) a fluoride, (4) a bromide

10. An unknown salt is a white crystalline solid. A drop or two of NaOH placed on a small amount of the dry salt gave a strong odor of ammonia. A few drops of $AgNO_3$ solution added to a solution of the unknown salt gave a white precipitate which did not dissolve in HNO_3. The formula of the salt is ....
(1) NH_4SO_4, (2) NaCl, (3) NH_4Cl, (4) HCl

Equations

1. $NaCl + H_2SO_4$ ...... /// .... + ...
2. $CaF_2 + H_2SO_4$ ...... /// .... + ...
3. $KI + MNO_2 + H_2SO_4$ ...... /// .... + ... + ...

Problems

1. What weight of iodine would be needed to make 100 g. of zinc iodide, ZnI_2?
2. How many grams of silver chloride can be prepared from 20 g. of sodium chloride?
3. How much bromine is contained in 100 g. of potassium iodide?

Chemistry II—Unit Test

The Periodic Table and the Nitrogen Group

Place a + before each *true* statement and a 0 before each *false* statement.

True and False

1. Davy developed the Periodic Table.
2. In the early periodic tables the elements were arranged according to atomic weights.
3. Three different persons worked on periodic tables at about the same time.
4. The idea of valence was clearly understood as early as 1860.
5. The periodic repetition of properties of elements arranged according to atomic weights is called the Law of Octaves.
6. Law of Octaves comes from the word October.
7. Mendelejeff knew about 60 elements.
8. The gaps in the Periodic Table indicate undiscovered elements.

True and False

9. Valences of elements are easily determined from the Periodic Table.
10. The properties of undiscovered elements can be forecast by using the Periodic Table.
11. At the present time we know 100 elements.
12. Valence is determined by the number of electrons in the outmost ring.
13. The very heaviest elements hold their outside electrons firmly.
14. The very heaviest elements tend to be radioactive.
15. It is necessary to study all the elements to understand chemistry.
16. The Periodic Table has simplified the study of chemistry.
17. The elements studied in this unit are phosphorus, antimony, bismuth, and arsenic.
18. Nitrogen is a solid.
19. Bismuth has the highest atomic weight of the four elements studied in this unit.
20. Nitrogen and phosphorus are strongly acid-forming.
21. The name phosphorus means "light-bearer."
22. Phosphorus was discovered by an alchemist.
23. About one-fourth of the bones and the teeth of animals contain phosphorus.
24. Phosphorus is found in beans, peas, cheese, meat, and bread.
25. Phosphorus is obtained by heating a mixture of calcium phosphate, sand, and coke.
26. Phosphorus vaporizes at a low temperature.
27. Glue is used in making matches.
28. Friction matches are better for home use than safety matches.
29. Arsenic generally is found with copper and iron.
30. Arsenic is used in the manufacture of lead shot.
31. Arsenic compounds are poisonous.
32. Paris green is a phosphorus and copper compound.
33. Arsenates of calcium and lead are used as insecticides.
34. Alloys of antimony usually are hard.
35. Babbitt metal is an alloy of bismuth and tin.
36. Antimony sulfide is used in fireworks to produce a blue light.
37. Bismuth alloys are remarkable for their low melting points.

True and False

38. Antimony is used in fire sprinkling systems.
39. Bismuth alloys are used to close gas mains in case of fire.
40. Rose's metal contains bismuth.
41. Rose's metal melts at a temperature below that of boiling water.
42. Bismuth subnitrate is used in x-raying the intestinal tract of human beings.
43. Antimony sulfides are found in nature, usually associated with Cu and Fe.
44. Lead shot is made with small round iron forms.
45. Phosphorus oxide plus water makes phosphoric acid.
46. White phosphorus is very poisonous.
47. Antimony sulfide is used in the heads of safety matches.
48. Potassium chlorate is used as oxidizing material in matches.
49. A safety match can be ignited by stepping on it.
50. Phosphorus may be handled safely with bare hands.
51. Lead, antimony, and tin are used in type metal.
52. Phosphorus is decidedly metallic in its physical properties.

Completion Questions

1. .... is given credit for originating the Periodic Table.
2. .... improved the Periodic Table through the study of electrons.
3. We now know .... elements.
4. An element having a negative valence of one may have a positive valence of ....
5. Three elements which do not fit into the Periodic Table are ...., ..., and ....
6. The symbol for phosphorus is ....; for antimony, ...; for bismuth, ...; and for arsenic, ...
7. In preparing phosphorus, ... and .... pass off as vapors, and .... is used to condense them.
8. Two forms of phosphorus are .... and ....
9. The melting point of phosphorus is .... degrees C. and its kindling temperature is .... degrees C.
10. Heat produced by slow oxidation makes phosphorus .... at room temperature.

11. The formula for phosphoric oxide is .... ; for phosphorus oxide, ... ; and for phosphoric acid, ...
12. The atomic weight of phosphorus is .... ; of antimony, ... ; of bismuth, ... ; and of arsenic, ...
13. The formula for sodium acid phosphate is .... ; for monocalcium acid phosphate is .... ; for calcium phosphate is .... ; for arsenic oxide is .... ; for antimony chloride is .... ; for antimony sulfide is .... ; for antimony oxide is ....
14. Six substances used in making matches are .... , ... , ... , ... , ... , and ....
15. Ammonium phosphate is used as .... material in making matches.
16. Place the number corresponding to the statement in column B at the right of the item in column A which it matches.

Column A	*Column B*
1. Phosphorus (white)	1. Bismuth, tin, cadmium, lead
2. $Bi(OH)_2(NO)$	2. Friction material
3. Wood's metal	3. Poisonous
4. Fusible plug	4. Used in preparing phosphorus
5. $K(SbO)\ (C_4H_4O_6)$	5. Sprinkler system
6. Red phosphorus	6. X-rays
7. Glass	7. Melts at 271° C.
8. Babbitt	8. Valence of + 1
9. Bismuth	9. Machine bearings
10. Coke	10. Nonpoisonous
	11. Tartar emetic
	12. Soluble in alcohol
	13. Nilson

Give the equations for

1. The preparation of phosphorus.
2. The preparation of arsenic.
3. How many grams of antimony chloride can be made by sprinkling 10 g. of powdered antimony into an adequate supply of chlorine?
4. How many grams of antimony can be made from 1 kg. of antimony sulfide?

Chemistry Mastery Test—Carbon

Use + for *True* and 0 for *False.*

True and False

1. Carbon has four electrons in the outmost ring.
2. Carbon forms compounds by sharing electrons.
3. Organic chemistry is a study of the compounds of carbon.
4. Carbon is found only in animate nature.
5. Every living thing contains carbon compounds in its tissues.
6. The growth of a plant is very largely a process of chemical action.
7. The study and practice of medicine tends more and more to center about chemistry.
8. Diamonds are a compound of carbon.
9. The value of diamonds as jewels is due to the cost.
10. Diamonds are the hardest substance known.
11. Graphite is an allotropic form of carbon.
12. The United States has no diamonds.
13. Graphite is often used as a lubricant where high temperatures prevent the use of oil.
14. All forms of carbon melt easily.
15. Graphite is used as electrodes in electric furnaces.
16. Graphite is known only in the natural form.
17. Carbon has three allotropic forms.
18. Soot, lamp black, and the black substance in coal are amorphous carbon.
19. Carbon does not dissolve in any of our common solvents.
20. Carbon is inactive at ordinary temperatures.
21. Carbon is unfit for use as a paint pigment.
22. Carbon reacts readily with acids and bases.
23. Carbon will react readily at high temperatures.
24. Calcium carbide is used to make acetylene.
25. Carborundum is the hardest artificial compound.
26. Carbon disulfide is very inflammable.
27. Carbon disulfide is a valuable solvent for rubber.
28. Carbon tetrachloride is used in fire extinguishers.
29. Coal is pure carbon.

True and False

30. There are two chief forms of coal and many less important varieties.
31. Anthracite contains less than 75 per cent uncombined carbon.
32. Coke gives off the most heat per ton.
33. Wood charcoal is made by destructive distillation of wood.
34. Bone black is obtained by heating bones in a shortage of air.
35. Oil coke collects in retorts used in distilling petroleum.
36. There is one part of CO_2 to four parts of nitrogen in the air.
37. Natural processes of fermentation and decay furnish CO_2 to the air.
38. "Choke damp" is composed of carbon monoxide.
39. A test for carbon dioxide is silver nitrate.
40. CO_2 is insoluble in water.
41. "Dry ice" is solid carbon dioxide.
42. Carbonic acid is a weak acid.
43. Soda water is a solution of CO_2 in water under pressure.
44. Carbon monoxide is nonpoisonous.
45. Carbon monoxide is prepared in the laboratory by dehydrating formic acid.
46. Natural gas consists largely of hydrogen.
47. Water gas is made by passing steam over heated coal.
48. When mixed with air, gasoline is highly explosive.
49. In the carburetor of an automobile, gasoline vaporizes and mixes with air.
50. The light of a candle is due to incandescent carbon particles.

Please fill in the correct word:

51. The three allotropic forms of carbon are ...., ..., and ....
52. .... is used in lead pencils.
53. The formula for calcium carbide is ....; for Carborundum ....; for carbon disulfide ....; and for carbon tetrachloride ....
54. The value of coal usually is determined by the amount of ....
55. Anthracite coal contains over .... per cent of uncombined carbon.

56. Two chief forms of coal are .... and ....
57. Other minor forms of coal are ...., ..., and ....
58. Bone black absorbs ....
59. The residue from making coal gas or distilling petroleum is ....
60. Green leaves contain .... which, by using .... as energy, is able to cause an action between .... and .... to form ....
61. CO_2 in coal mines is called ....
62. CO_2 is prepared by using .... and ....
63. Fire extinguishers which give off CO_2 employ .... and .... to produce the gas. The "Foam" type uses .... which forms .... as a precipitate.
64. "Foam" extinguishers are used for .... fires.
65. Incomplete combustion of carbon forms ....
66. A gas formed from heating coal in a retort is .... gas. .... is left as a residue and the process is called ....
67. Passing steam through hot coal produces .... gas.
68. Minor products formed from heating coal in a retort are ...., ..., and ....
69. The formula for acetylene is ....; for ethyl alcohol ....; for wood alcohol ....; and for carbonyl radical ....
70. When heavier hydrocarbon molecules are broken up by pressure and heat, it is called ....
71. Petroleum products are separated by .... distillation.
72. When mixed with ...., gasoline is highly explosive.
73. When the combustion is very rapid, such a mixture of gases is called an .... mixture.
74. In the .... of an automobile, gasoline vaporizes and mixes with air.
75. .... was the first fuel obtained from petroleum.
76. The most important "antiknock" compound is .... Its formula is ....
77. Ease of .... is an important characteristic of gasoline.
78. When a stream of gas burns, a .... is produced.

Complete the following equations:

$CuO + C$	$CHx + O_2$
$CaO + Q$	$CO_2 + H_2O$
$CaC_2 + H_2O$	$CaCO_3 + HCl$
$SiO + C$	$H_2CO_3 + NaOH$
$C + S$	$NaHCO_3 + HKC_4H_6O_4$

Identify:

Cream of tartar, leavening, carbonyl, coal gas, water gas, natural gas, produce gas, hydrocarbon, casing-head gasoline, coke, photosynthesis, choke damp, lamp black, peet, and cannel coal.

CHEMISTRY—*Second Semester*

Final Examination:

PART I

Indicate in the blank at the left of each question the number of the answer which is most nearly correct.

.... 1. Most of the nitrogen in the world occurs: (1) in the ocean; (2) in silicate rocks; (3) in Chile; (4) as free nitrogen; (5) as nitric acid.

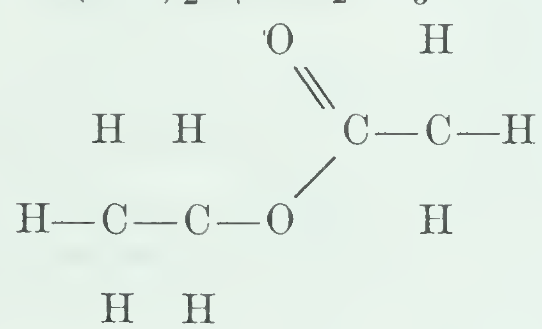
.... 2. $3H_2 + N_2 = 2NH_3$ is the equation for the reaction in the (1) Ostwald process; (2) Haper process; (3) Solvay process; (4) lead chamber process; (5) contact process.

.... 3. When H_2S is oxidized to SO_2, the valence change of sulfur is: (1) 2; (2) 8; (3) 4; (4) 6; (5) 0.

.... 4. The valence of Mo in $(NH_4)_2MoO_4$ is: (1) 2; (2) 4; (3) 5; (4) 6; (5) 7.

.... 5. The elements in Column V of the Periodic Table, with their atomic weights, are: N 14, P 31, As 75, Sb 122, Bi 209. The oxide which is most acidic is therefore: (1) As_2O_3; (2) P_2O_3; (3) Sb_2O_3; (4) N_2O_3; (5) Bi_2O_3.

.... 6. If the oxides of the elements mentioned in Question 5, preceding, are arranged in order of their molecular weights (lightest to heaviest), *amphoteric* properties are most evident in: (1) those at the beginning of the series; (2) all of them; (3) those in the middle of the series; (4) the last one in the series; (5) none of them.

7. The fact that sulfur occurs in two solid forms is designated by the term: (1) amphoterism; (2) oxidation-reduction; (3) periodic variation; (4) allotropy; (5) isotopy.
8. Sulfur is in its most reduced condition in: (1) SO_2; (2) S; (3) H_2SO_4; (4) Na_2SO_3; (5) H_2S.
9. One of the following is *not* a property of concentrated HNO_3: (1) reducing agent; (2) acid; (3) will react with copper; (4) oxidizing agent; (5) can be reduced by zinc.
10. To obtain NH_3 gas, unmixed with any other gas, from NH_4CL, one would treat it with: (1) conc. H_2SO_4; (2) Zn; (3) conc. NaOH; (4) heat; (5) CO_2.
11. One of these reactions will *not* produce CO_2 gas. Which is it? (1) $Ca(HCO_3)_2$ + heat =; (2) $CaCO_3$ + HCL = ; (3) heating dry ice; (4) burning paper; (5) $Ca(OH)_2 + Na_2CO_3$.
12.  is the formula for: (1) an alcohol; (2) soap; (3) an acid; (4) an ester; (5) acetaldehyde.
13. One of the following statements is *not* true of *sodium:* (1) shows a valence of +1; (2) is a member of the alkaline earth group of elements; (3) is an active metal; (4) is lighter than water; (5) is obtained from NaOH by electrolysis.
14. One of these ions is *not* a member of Group II of the analysis scheme for the anions: (1) PO_4^{---}; (2) BO_3^{---}; (3) NO_3^-; (4) F^-; (5) SO_4^{--}.
15. The reducing agent most used to smelt iron from its ores is: (1) electric current; (2) aluminum (Goldschmidt process); (3) hydrogen; (4) carbon; (5) limestone.

16. One of the following sulfides which is precipitated in Group II (cations) can be distinguished from the others by its color. Which is it? (1) HgS; (2) CdS; (3) CuS; (4) Bi_2S_3; (5) PbS.
....
17. One of the sulfides listed above is *not* soluble in dilute HNO_3 (5 ml. HNO_3 to 10 ml. H_2O). It is: (1) HgS; (2) CdS; (3) CuS; (4) Bi_2S_3; (5) PbS.
....
18. One of the following cations is identified by a yellow flame test: (1) Ba^{++}; (2) Ca^{++}; (3) K^+; (4) Mg^{++}; (5) Na^+.
....
19. One of the ions listed in Question 18, preceding, gives *no* flame test. It is: (1) Ba^{++}; (2) Ca^{++}; (3) K^+; (4) Mg^{++}; (5) Na^+.
....
20. In analyzing several kinds of baking powder, one would *not* expect to find much evidence of one of the following substances in any of the baking powders: (1) $NaHCO_3$; (2) $Ca(H_2PO_4)_2$; (3) alum; (4) NaCl; (5) cream of tartar.
....
21. One of the following substances is *not* a cause of hard water: (1) Na_2CO_3; (2) $Ca(HCO_3)_2$; (3) $MgSO_4$; (4) $CaSO_4$; (5) $Mg(HCO_3)_2$.
....
22. The hardness of La Crosse city water in parts per million of $CaCO_3$ is: (1) 0.240; (2) 2.40; (3) 240; (4) 2400; (5) 2,400,000.
....
23. One of the following substances is *not* used as a water softener: (1) Na_3PO_4; (2) Na_2CO_3; (3) Na_2SO_4; (4) $Na_2B_4O_7$; (5) zeolite.
....
24. One of these ionic reactions will *not* go to completion. Which is it:
    (1) HCL + NaOH– –
    (2) $NaNO_3$ + KCL– –
    (3) $CuCl_2$ + H_2S– –
    (4) Na_2CO_3 + 2HCL– –
    (5) NH_4Cl + NaOH– –
....
25. The Basic Open Hearth process for purifying iron is so called because:
    (1) It was invented by John Basic.

(2) The iron is washed with NaOH solution.

(3) It is one of the fundamental processes in making steel.

(4) Iron is a base metal.

(5) Acid impurities are removed by combining with the furnace lining.

PART II

This part of the test is divided into six sections. The questions are of the matching type. It is well to attempt to answer all questions even though you may be doubtful of some answers.

Section 1: ALUMINUM

.... 1. Charles M. Hall	1. $Al_2O_3.2H_2O$
.... 2. Wohler	2. $Fe_2O_3 + 2Al = Al_2O_3 + 2Fe$
.... 3. Bauxite	3. $Al(OH)_3$
.... 4. Cryolite	4. The first man to prepare aluminum
.... 5. Thermite process	5. $Al_2O_3.2SiO_2.2H_2O$
.... 6. A mordant	6. Invented an economical process for preparing aluminum
.... 7. Alum	7. Na_3AlF_6
.... 8. Kaolin	8. $KAl(SO_4)_2.12H_2O$
.... 9. Aluminum powder	9. Hoopes process
.... 10. "Alclad"	10. Used in making mirrors
	11. Duralumin coated with high purity aluminum
	12. Parkes process

Section 2: ALKALINE EARTH METALS AND THEIR COMPOUNDS

.... 1. Heavy spar	1. $(CaSO_4)_2.H_2O$
.... 2. Plaster of Paris	2. $CaCO_3$
.... 3. Marble	3. $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$
.... 4. Slaked lime	4. $BaSO_4$
.... 5. The reaction in mortar when it "sets"	5. $CaCO_3 + \text{heat} = CaO + CO_2$

.... 6. Making of quicklime		6. $NaCl + NH_3 + H_2O + CO_2 = NaHCO_3 + NH_4Cl$
.... 7. Dolomite		7. $Ca(OH)_2$
.... 8. Solvay process		8. Na_2CO_3
.... 9. Reaction in a tartrate baking powder		9. $NaOH$
.... 10. Soda ash		10. $NaHCO_3 + KHC_4H_4O_6 = CO_2\uparrow + H_2O + KNaC_4H_4O_6$
		11. $Na_2CO_3 + CaCN_2 + C = 2NaCN + CaCO_3$
		12. $CaCO_3.MgCO_3$

Section 3: TESTS FOR IONS

Ions tested for	Testing reagent(s)
.... 1. PO_4^{---}	1. Lead acetate paper
.... 2. CO_3^{--}	2. K_2CrO_4 solution
.... 3. S^{--}	3. Cl_2 water (CCl_4 present)
.... 4. BO_3^{---}	4. $Al(OH)_3$
.... 5. SO_4^{--}	5. H_2SO_4 + alcohol; ignite
.... 6. I^-	6. KSCN solution
.... 7. NO_3^-	7. Flame test
.... 8. Pb^{++}	8. $HNO_3 + (NH_4)_2MoO_4$ solution; heat
.... 9. Fe^{+++}	9. Dimethyl glyoxime
.... 10. Na^+	10. 6N H_2SO_4; test evolved gas with $Ca(OH)_2$
	11. $FeSO_4$ solution conc. H_2SO_4
	12. Barium acetate solution (HCl present)

Section 4: MANUFACTURING PROCESSES

.... 1. Le Blanc process	1. Method of making HNO_3 from N_2 and O_2 of the air
.... 2. Haber process	2. Method of concentrating sulfide ores
.... 3. Ostwald process	3. Method of purifying iron by blowing air through the melted iron
.... 4. Frasch process	4. Method for making H_2SO_4
.... 5. Flotation process	
.... 6. Birkeland-Eyde process	
.... 7. Hoopes process	

.... 8. Bessemer process	5. Method for making Na_2CO_3
.... 9. Goldschmidt process (Thermite)	6. Method for separating gold from its ores
........10. Contact process	7. Method of making ammonia
	8. Method of making HNO_3 from NH_3
	9. Method of obtaining metals from their oxides by reaction with powdered aluminum
	10. Method of mining sulfur
	11. Method of softening water
	12. Method of purifying aluminum

Section 5: Balancing Equations

Match the equations in column I with the coefficients in column II which balance the *left-hand side* of the equation. Coefficients are given in proper order. (Note: The entire equation must be balanced to get the correct coefficients for the left-hand side.)

.... 1. .... NH_3 + ... $O_2 = NO + H_2O$	1. 1, 1
.... 2. .... HNO_3 + ... $Ag = AgNO_3 + NO + H_2O$	2. 2, 3
.... 3. .... $KMnO_4$ + ... $HCl = KCl + MnCl_2 + Cl_2 + H_2O$	3. 3, 2, 10
.... 4. .... HNO_3 + ... $Sn = HSnO_3 + NO_2 + H_2O$	4. 1, 5, 8
.... 5. .... $Bi(OH)_3$ + ... $Na_2SnO_2 = Bi + Na_2SnO_3$	5. 4, 5
.... 6. .... HNO_2 + ... $HI = I_2 + H_2O + NO$	6. 4, 3
.... 7. .... $K_2Cr_2O_7$ + ... $S = K_2SO_4 + Cr_2O_3$	7. 3, 3
.... 8. .... H_2S + ... $KMnO_4$ + ... $HCl = S + MnCl_2 + KCl + H_2O$	8. 4, 1
.... 9. H .... H_2SO_3 + ... $KmnO_4 + HCl = H_2SO_4 + CrCl_3 + KCl + H_2O$	9. 5, 2, 6
........10. .... $AgBr$ + ... $FeSO_4 = Ag + Fe_2(SO_4)_3 + FeBr_2$	10. 3, 8
	11. 2, 16
	12. 2, 2

Section 6: MISCELLANEOUS

.... 1. Lithopone	1. Mostly $CaSiO_3$
.... 2. Ferrum	2. Iron drawn off from the blast furnace
.... 3. Pyrites	3. A rapid method for making steel
.... 4. Hematite	4. Latin name for tin
.... 5. Stannum	5. Ore containing Fe_2O_3
.... 6. Slag	6. Heating a sulfide ore in contact with air
.... 7. Roasting	7. Meteoric iron
.... 8. Smelting	8. Ore containing Fe_3O_4
.... 9. Magnetite	9. Heating an ore with a reducing agent
..................10. Pig iron	10. FeS_2
	11. Latin name for iron
	12. Mixture of $BaSO_4$ and ZnS

UNIT—HOW LIVING THINGS MAINTAIN THEIR KIND[1]

Unit Organization

I. Unit Theme: All plants and animals maintain their kind.

II. Major Concepts: Plants and animals, in order that their kind can exist for generations, are equipped with many different kinds of reproduction.

III. Objectives

A. Aims

1. Health: By learning how the microscopic plants and animals grow and reproduce, the pupil will know better how to control them.
2. Worthy use of leisure: With genuine interest and knowledge of reproduction, he can develop an experiment with plants and animals as a hobby.
3. Vocational: The pupil may become interested in bacteriology, horticulture, agriculture, animal husbandry, and take up one of these interests as a life work.

[1] Prepared by William Holak.

4. Ethical character: By knowing that germs and bacteria may come from sneezing, coughing, and spitting, he may better practice personal cleanliness.

B. General Objectives
1. To develop a greater appreciation and interest in living things.
2. To develop the scientific attitude.
3. To increase skill in the use of the scientific methods.

C. Specific Objectives
1. To learn how different plants and animals reproduce.
2. To make pupils aware of the fallacious ideas of some people, of how microscopic beings come into existence.
3. To learn how to control reproduction of certain kinds of plants and animals.
4. To learn of the different kinds of plants and animals.
5. To learn the functions of reproductive parts of plants and animals.
6. To learn how parents provide and care for their young.

IV. Major Problems
A. What is the nature of reproduction?
B. How are the more complex methods of reproduction secured?
C. How do parents care for their young?

V. Pupil Activity
A. Write answers to questions on guide sheets.
B. Make diagrammatic sketches of plants and the various parts of their life histories.
C. Perform experiments.
D. Prepare and give special reports.
E. Take part in class discussion.
F. Observe and study outside of class.

VI. Teacher Activity
A. Provide and administer work on guide sheet.
B. Lead class discussions.
C. Prepare and give demonstrations.
D. Motivate further study.
E. Provide extra references.

F. Supervise study of pupils.
G. Test results.
H. Interpret results.

VII. References
A. Pieper, Beauchamp, and Frank (Text): "Problems in Biology."
B. Moon and Mann: "Biology."
C. Curtis, Caldwell, and Sherman: "Biology for Today."

Unit Administration

I. Introduction and Attack
A. Objectives
1. Find out what pupils already know.
2. Motivate further study.
B. Procedure
1. If possible, show film: "Seed Dispersal," "Reproduction in Mammals."
2. Give an oral pre-test.
3. Give short presentation.
4. Integrate the pre-test and presentation as much as possible.

Presentation

In order that plants and animals can maintain their kind, nature has equipped them with different methods of reproduction. There are several biological terms we must master before we can appreciate this unit. (Then ask first questions of the pre-test.)

Pre-test. (Discuss questions briefly.)
1. What is meant by reproduction?
2. What is fission?
3. Name some animals that reproduce by fission.
4. What is regeneration?
5. What is meant by budding?
6. How do some common plants reproduce?
7. What is a rhizome?
8. What is asexual reproduction?
9. How does sexual reproduction differ from asexual reproduction?

10. What is pollination?
11. How are plants pollinated?
12. Name some animals that reproduce or hatch from eggs.
13. What stages does a June bug go through before it grows to maturity?
14. How do some parents protect their young?
15. How do parents generally feed their young?
16. Why do the young of higher animals need more parental care than those of lower animals?

II. Study and Work Period
  A. Second Day
    1. Objectives
      a. Motivate (create more interest in the unit).
      b. Devise method of attack.
      c. To develop appreciation of reproduction.
    2. Procedure
      a. Pick out some interesting part in the unit and tell the class about it.
      b. Class discussion.
      c. Supervised study.
  B. Third Day
    1. Objectives
      a. Motivation.
      b. Appreciation of simple kinds of reproduction.
      c. Learn about reproduction in the simplest plants.
    2. Procedure
      a. Class discussion.
      b. Use charts and diagrams.
      c. Supervised study.
  C. Fourth Day
    1. Objectives
      a. Appreciation of generation.
      b. Learn about asexual reproduction.
    2. Procedure
      a. Class discussion.
      b. Reports.
      c. Supervised study.

D. Fifth Day
  1. Objectives
    a. New knowledge.
    b. New problem presented.
    c. Motivation.
  2. Procedure
    a. Short overview of problem.
    b. Discussion of different level assignments.
    c. Supervised study.

E. Sixth Day
  1. Objectives
    a. Motivation.
    b. Appreciation of more complex methods of reproduction.
    c. Learn about fertilization.
  2. Procedure
    a. Class discussion.
    b. Reports.
    c. Show through microscope paramecia and spiro gyra.
    d. Supervised study.

F. Seventh Day
  1. Objectives
    a. Appreciation of specialized organs for reproduction.
    b. Learn about pollination.
    c. Knowledge about different parts of a flower.
  2. Procedure
    a. Class discussion.
    b. Laboratory with a plant (flower).

G. Eighth Day
  1. Objectives
    a. Motivation.
    b. Present a new problem.
  2. Procedure
    a. Pass out new study sheet.

b. Discuss different level assignments.
c. Supervised study.

H. Ninth Day
1. Objectives
a. Motivation.
b. Appreciation of how certain parents provide for the young.
2. Procedure
a. Class discussion.
b. Reports.
c. Supervised study.

I. Tenth Day
1. Objectives
a. New knowledge.
b. Appreciation of ways young are supplied with food.
2. Procedure
a. Class discussion.
b. Reports.
c. Supervised study.

J. Eleventh Day
1. Objectives
a. Appreciation of how parents protect their young.
b. Learn how helpless are human beings at birth.
2. Procedure
a. Class discussion.
b. Reports.
c. Supervised study.

III. Appraisal and Outcome
A. Twelfth Day
1. Objectives
a. Appreciation of unit as a whole.
b. Correct incorrect ideas.
c. Point out basic ideas or points in the unit.
2. Procedure
a. Class discussion.
b. Summary by either teacher or pupil.

B. Thirteenth Day
  1. Objectives
    a. Aid students to see if they have learned the basic parts of the unit.
  2. Procedure
    a. Give discussion question review test and then discuss it in class.

C. Fourteenth Day
  1. Objectives
    a. Test to see how much pupils have learned.
  2. Procedure
    a. Administer mastery test and score in class.

Study Sheet

Unit Theme: All plants and animals have means of maintaining their kind.

Central Idea: All plants and animals are able to maintain their kind because of the many types of reproduction bestowed upon them by nature.

Problem 1: What is the nature of reproduction?

Assignment A: Read chapter XXXV, pp. 439–445, and answer the questions on this sheet.

1. What is reproduction?
2. What is meant by binary fission?
3. Explain how paramecium reproduces.
4. What is budding?
5. What plants reproduce by budding?
6. What is a sporangium?
7. Name at least seven plants that reproduce by spores.
8. Explain how ameba reproduce.
9. Name some animals that reproduce by spores.
10. What is meant by regeneration? Give examples.
11. Of what value is regeneration in plants?
12. Give three examples of each of the following: tuber, rhizome, and bulbs.
13. What is asexual reproduction?

14. Explain how sexual reproduction differs from asexual reproduction.

Assignment B:

1. Give a full account of the reproduction of bread mold, ameba, or paramecium. Make drawings showing various stages.
2. Make a report on Pasteur and his work.
3. Make a report on Robert Koch.

Assignment C:

1. Visit a greenhouse and find out how different plants are propagated, then report to the class.
2. Do experiment 35 · "How can new plants be reproduced by generation?"
3. Do experiment 34: "How does bread mold reproduce?"

Study Sheet

Unit Theme: All plants and animals have means of maintaining their kind.

Central Idea: All plants and animals are able to maintain their kind because of the many types of reproduction bestowed upon them by nature.

Assignment A: Read pp. 445–454 and write out answers to these questions.

Problem 2: How are the more complex methods of reproduction secured?

1. Explain the reproduction of the ulothrix.
2. What are isogametes?
3. What is fertilization?
4. Give a full account of the reproduction of oedogonium.
5. Explain the difference between conjugation and fertilization.
6. Give a full account of the reproduction of spirogyra.
7. Describe the reproductive organs of the moss.
8. How do the spores of moss develop?
9. What are the protonema?
10. In what ways is pollination brought about?
11. Explain how the pollen and ovules unite to form a seed.

12. What is the calyx?
13. How does fruit aid in dissemination of seed?
14. Name three advantages of cross-pollination.
15. Name four ways by which plants cross-pollinate.
16. How does cross-fertilization take place in the earthworm?
17. Explain advantages of reproduction of the rabbit over reproduction of the ameba.

Assignment B:

1. Make a report on how hybrid corn is produced.
2. Make a drawing of the different parts of a flower.
3. Make a report on reproduction of salmon or trout.

Assignment C:

1. Do experiment 36, p. 170.
2. Make a drawing of each of the stages of the life history of wheat, fern, or moss.
3. Make a comparison of sexual and asexual reproduction and make a list of advantages of each.

Mastery Test

How Plants and Animals Are Able to Maintain Their Kind

True and False

Use + for *True* and 0 for *False.*

1. The ameba has a highly developed type of reproduction.
2. Paramecia reproduce by fission.
3. A pelican lays many eggs at one time.
4. The flatworm does not reproduce by fission.
5. Yeast reproduces by budding.
6. The essential difference between fission and budding is the size of the parent and the offspring.
7. Invertebrate animals have no backbone.
8. The sporangium is the part of the mold that contains the spores.
9. Mycelium is another name given to the backbone of some animals.
10. The sporangia generally contain 15 or 20 spores.
11. Spores of some fungi are often found thousands of feet in the air.

True and False

12. Ameba sometimes reproduce by spores.
13. Malarial fever attacks the skin first.
14. Malarial fever is spread by the hookworm.
15. If a starfish is cut to pieces it is sure to die.
16. Starfish eat many young oysters.
17. As we pass from the lower animals to the upper animals the power of regeneration is increased.
18. Rhizomes are stems found above the ground.
19. Some plants produce horizontal stems known as runners.
20. Higher animals such as the mammals cannot replace lost parts.
21. Reproduction by fission and budding is the same thing.
22. In sexual reproduction there is always a fusion of two cells before the growth of the new individual.
23. Gametes are the same things as spores.
24. Gametes develop directly into new plants.
25. The female gamete is known as the sperm.
26. The fusion of the sperm with the egg is known as fertilization.
27. Conjugation results in a rejuvenation of the paramecium.
28. Spirogyra has a spherical appearance.
29. The archegonia of the moss produces the sperm cells.
30. The contents of two spirogyra fuse and form a zygote.
31. Water is required for the reproduction of moss.
32. The protoplasm of the capsule divides and forms a large number of spores.
33. The protonema is another name given to the antheridium.
34. The moss has a more complex method of reproduction than the ulothrix.
35. The stigma is found at the top of the pistil.
36. The stigma of most plants is sticky.
37. The fertilized egg develops into an embryo.
38. In cross-pollination, the pollen from the stamen reaches the stigma of the same flower.
39. The fruit is of no importance to the seed.
40. Nature has provided for special ways of cross-pollination.
41. In higher animals each individual is capable of producing sperms and eggs.

True and False

42. In the reproduction of fish the egg is fertilized after it is laid.
43. It is very necessary for amebas and paramecia to take good care of their young.
44. Fish, frogs, and reptiles lay thousands of eggs which usually hatch and grow into full maturity.
45. Grasshoppers lay their eggs in hard soil to keep them from getting wet.
46. The young blister beetle feeds on grasshopper eggs.
47. Young spiders are very cannibalistic.
48. Salmon lay their eggs in salt water of the ocean.
49. Chickens have certain calls with which they can warn their young.
50. Both pistillate and staminate flowers are found on the same willow tree.

Completion

1. Maggots and .... are closely related.
2. .... proved that microscopic plants and animals do not arise spontaneously.
3. Reproduction by cell division is known as ....
4. .... and .... are examples that reproduce by this method.
5. The .... made it possible to study single-celled plants and animals.
6. The .... feeds its young by letting them eat partly digested food from its throat.
7. The growing of new parts after losing them is known as ....
8. The potato is an example of a ....
9. The gladiolus is an example of a ....
10. The runners on strawberries are called ....
11. Yeasts reproduce by ....
12. In .... reproduction there are no special cells for reproduction.
13. The ulothrix reproduces by the fusion of ....
14. The fusion of the sperm with the egg is ....
15. Two gametes of a spirogyra fuse and form a ....

16. The .... of the moss bears the sperms.
17. .... is necessary for fertilization to take place in the mosses.
18. Conjugation of paramecia results in a .... of the two paramecia.
19. The fertilized egg of a moss divides, forming the .... which anchors the plant, which in turn grows a hairlike structure, the ...., which enlarges, forming the ....
20. The spore of the moss germinates and grows into the ....
21. The passage of the pollen to the stigma is known as ....
22. The fertilized egg develops into the ....
23. The passing of pollen from the stamens of one flower to the stigma of another is ....
24. The difference of offspring from parents is known as ....
25. The higher animals are classed as .... and ....
26. The young blister beetle feeds only on ....
27. Young spiders are very ....
28. The salmon lays its eggs in .... water.
29. The laying of eggs by fish is known as ....
30. The .... does not build a nest but lays its eggs in the nests of other birds.
31. Scratching birds such as chickens are covered with .... when hatched.
32. .... are animals that line their nests with fur.
33. .... are the most helpless creatures at birth.
34. The unlearned reactions in animals below man are ....
35. Name the six parts of the flower.
36. Give a full account of the life history of moss, wheat, butterfly, mosquito, and honeybee.

UNIT—CALCIUM AND ITS COMPOUNDS[1]

Unit Organization

I. *Unit Theme:* Calcium and calcium compounds are important in our everyday living.

II. *Central Idea:* Calcium and its compounds are very common and useful to man and it is important that we know of their properties and uses.

[1] Prepared by William Holak.

III. Objectives
   A. Aims
      1. Vocational: Interest in this unit may develop into a life work in chemistry.
      2. Worthy use of leisure: Research or experimentation may develop into a hobby.
      3. Citizenship: Knowledge about calcium may better enable you to understand problems about why certain things are done as they are.
      4. Worthy home membership: You may learn about water softening, building and use of calcium salts which may make you a better home member by applying these principles.
   B. General Objectives
      1. To achieve increased knowledge of the subject of chemistry.
      2. To develop a scientific attitude toward the application of principles of chemistry.
      3. To develop a greater appreciation of and greater skill in the use of scientific methods.
   C. Specific Objectives
      1. To learn where calcium is in existence.
      2. To learn the properties of calcium.
      3. To learn about compounds of calcium in water.
      4. To learn the many uses of calcium.

IV. Major Problems
   A. How does calcium occur in nature?
   B. What are the properties of calcium?
   C. What are the important compounds of calcium?
   D. What are the common uses of calcium and its compounds?

V. Pupil Activity
   A. Write answers to questions.
   B. Individual experimentation in laboratory.
   C. Participate in class discussion.
   D. Special reports given to class or written and handed in.
   E. Study outside of class as well as during directed study periods.

VI. Teacher Activity
   A. Guide and motivate study during directed study periods, laboratory periods, and outside of class.
   B. Lead class discussion.
   C. Plan demonstrations and individual experiments.
   D. Perform demonstrations.
   E. Provide references.
   F. Make out and administer tests.

VII. References
   A. Text (Brownlee, Fuller, Hancock, Sohon, Whitsit: "First Principles of Chemistry").[2]
   B. Library references.

Unit Administration

I. Exploratory Cycle (Introduction)
   A. Objectives
      1. To discover what pupils already know.
      2. To motivate study.
      3. To orient pupils and teacher.
   B. Procedure
      1. Give a short presentation.
      2. Oral pre-test.
      3. Integrate (1) and (2) as much as possible.
      4. Display samples of calcium compounds.
         a. Questions:
            (1) Where is calcium found on the activity table?
            (2) What effect does this have on the separation of calcium from its compounds?
            (3) How can it be separated from its compounds?
            (4) Where do we find calcium?
            (5) What are some uses of $CaCO_3$?
            (6) Name some other calcium compounds.
            (7) Where do we find these compounds?
            (8) What is hard water?
            (9) What is boiler scale?
            (10) How can water be softened?
            (11) What is a kiln?

[2] Published by Allyn and Bacon.

(12) What is slaked lime? What are its uses?
(13) What is plaster of Paris? What are its uses?

II. Presentation

We come in contact with calcium compounds every day of our lives. These compounds are so common that we have a tendency to overlook them. Calcium, being a very active metal, is hard to separate from its ores and it was not prepared commercially until 1900 when Hare developed the electrolytic process. $CaCO_3$ is the most common compound of calcium. Limestone, marble, and marl are the most common examples of this calcium compound. $CaSO_4$ is one of the compounds that makes water hard, but by applying certain principles of chemistry it can be softened. There are other calcium compounds which we will study with an emphasis upon their uses.

III. Study and Work
- A. Second Day
  1. Objectives
     - a. Motivate pupils to study.
     - b. Appreciation of water softening.
     - c. Acquire knowledge of physical and chemical properties of calcium.
     - d. Learn where calcium is most commonly found.
  2. Procedure
     - a. Class discussion.
     - b. Demonstration.
     - c. Supervised study.
- B. Third Day
  1. Objectives
     - a. To learn how water is softened.
     - b. Relate study with practical application.
  2. Procedure
     - a. Water-softening experiment in laboratory.
- C. Fourth Day
  1. Objectives
     - a. To motivate further study.
     - b. Appreciation of properties and uses of quicklime.

2. Procedure
    a. Class discussion.
    b. Demonstration.
    c. Supervised study.

D. Fifth Day
1. Objectives
    a. To motivate interest.
    b. To acquire knowledge of plaster casts and from what they are made.
    c. Knowledge of the uses of phosphates, chlorides of calcium.
2. Procedure
    a. Class discussion.
    b. Teacher demonstration.
    c. Supervised study.

E. Sixth Day
1. Objectives
    a. Appreciation of the practical use of bleaching powder.
    b. To learn of practical uses of bleaching powder.
2. Procedure
    a. Laboratory work on bleaching supervised by teacher.

IV. Appraisal and Outcome

A. Seventh Day
1. Objectives
    a. Appreciation and understanding of unit as a whole.
    b. To aid pupils in understanding certain parts.
    c. To point out basic points in the unit.
2. Procedure
    a. Integration of subject matter by teacher.
    b. Ask questions about certain parts of the unit.
    c. Clear up questions asked by pupils.

B. Eighth Day
1. Objectives
    a. To test what pupils have learned.
2. Procedure
    a. Administer mastery test and score in class.

Study Sheet

Calcium and Its Compounds

I. *Unit Theme:* Calcium and calcium compounds are of importance to all of us.

II. *Central Idea:* Calcium and calcium compounds are important to man; therefore it is important that we know about their properties and uses.

Assignment A: Read Chapter XXVIII, p. 485. Do the learning exercises on pp. 492, 498, and 503.

Learning exercises, p. 492:

1. Account for the difference in valences of Na and Ca.
2. At what electrode is Ca deposited? Why?
3. Is calcium at the present time to be regarded as a useful metal? Justify your answer.
4. State three differences between marble and limestone.
5. What is meant by hard water? How are such waters formed?
6. Why is hard water undesirable for washing purposes?
7. What is boiler scale? How is it formed?
8. Show by equations how temporary hard water can be softened in two ways.
9. Describe how caves in limestone are formed?
10. Give four important uses of calcium carbonate.

Learning exercises, p. 498:

1. Describe manufacture of quicklime. Write equations.
2. What are the advantages of using a rotary kiln?
3. What physical changes occur when lime is slaked?
4. Write a chemical equation for chemical change involved.
5. State three uses of calcium oxide.
6. Explain the sentence "Lime stands among the bases as sulfuric acid does among the acids."
7. What is limewater? For what gas is it used as a test?
8. Give five important uses of calcium hydroxide.
9. How is mortar made?
10. What changes take place when mortar sets?

Learning exercises, p. 503:

1. Give the formula for gypsum; for plaster of Paris.
2. Describe the process of making a plaster cast.
3. For what reason is normal calcium phosphate converted into the superphosphate in the manufacture of fertilizer?
4. What is the source of calcium chloride?
5. Give two uses of calcium chloride.
6. How is bleaching powder made?
7. Give steps in bleaching cotton, with reasons for each step.
8. Account for the disinfectant of bleaching powder.

Assignment B: Write out the answers to the exercises, pp. 504 and 505.

Assignment C:

1. Make a labeled drawing of a lime kiln and write out a complete explanation of how it works.
2. Visit a water-softening plant and report to the class on what you saw.
3. Visit a limestone or marble quarry and explain what you see.

Mastery Test

Calcium and Its Compounds

True and False

Use + for *True* and 0 for *False*.

1. Chalk is a form of calcium carbonate.
2. Pure calcium has a very brilliant appearance.
3. Carbonic acid will slowly dissolve calcium carbonate.
4. Permanent hard water can be softened by boiling.
5. Calcium hydroxide neutralizes acid anhydrides.
6. Good mortar increases in strength with age.
7. When quicklime and water react very little heat is produced.
8. Lime from rotary kilns slakes with water more rapidly and evenly than lime from other processes.
9. Calcium carbonate is used in the manufacture of cement.
10. Quicklime is known as calcium hydroxide.

True and False

11. Stalagmites are calcium carbonate icicles that hang from the ceilings of caves.
12. The water in La Crosse is classed as very hard.
13. Sodium carbonate is common washing soda.
14. Quicklime is used in making calcium carbide.
15. Powdered plaster of Paris is mixed with about two-thirds its weight of water.
16. Normal calcium phosphate is soluble in water.
17. A deliquescent substance has the property of taking up water from the air and dissolving in it.
18. Bleaching powder is a good disinfectant.
19. Soap softens temporary hard water.
20. Boiler scale is a form of calcium carbonate.
21. Slaked lime is used in making mortar.
22. The mineral matter of bones is essentially superphosphate of lime.
23. The addition of glue hastens the setting of plaster, while electrolytes retard it.
24. Calcium chloride is often used in ice-making.
25. The hardening of the interior of mortar is due chiefly to the escape of water.
26. When the bleaching powder, chloride of lime, is treated with an acid, chlorine is liberated.
27. When the plaster of Paris sets it decreases in volume.
28. Pure calcium metal is very soft.
29. About twice as much calcium sulfate as calcium carbonate is found in nature.
30. Calcite has the property of double refraction of light.
31. Soap will not soften hard water.
32. Calcium hydroxide is quite expensive to use as a base.
33. Calcium hydroxide, or slaked lime, is a white solid when pure.
34. A water solution of lime is rather strongly basic.
35. Calcium oxide is very inactive.
36. The formula for gypsum is $(CaSO_4) + H_2O$.
37. Stalactites are sodium carbonate icicles found in caves.
38. Calcium can be separated from its compounds by electrolysis.

39. Calcium oxide is often used to dehydrate alcohol.
40. Producer gas is often used in place of coal in the manufacture of quicklime.

Completion

1. The valence of calcium is ....
2. Calcium chloride is obtained as a by-product of the ....
3. Three forms of calcium carbonate are ...., ..., and ....
4. Molten calcium burns readily in oxygen and ....
5. Bleaching powder is made by passing .... over slaked lime.
6. Insoluble $Ca_3(PO_4)_2$ is made by passing .... over slaked lime.
7. Mortar hardens by .... of water and absorption of ....
8. CaO is made by heating ....
9. Softening permanent hard water requires the addition of ....
10. Hard water wastes soap and leaves a ....
11. The calcium (metal) can be removed from its compounds by .... of fused calcium chloride.
12. Caves are formed in limestone by the dissolving action of water containing ....

Multiple Choice

Underline the correct answer.

1. Calcite is a pure crystalline form of (a) gypsum, (b) calcium carbonate, (c) calcium oxide, (d) calcium sulfate.
2. Temporary hard water contains calcium or magnesium (a) chloride, (b) bicarbonate, (c) carbonate, (d) hydroxide.
3. When calcium unites with water, (a) oxygen, (b) CaO, (c) hydrogen, (d) calcium hydroxide is a product.
4. The first successful experiment of getting calcium from its compounds was performed by (a) Davy, (b) Bacon, (c) Priestley, (4) Hare, (e) Solvay.
5. The successful operation of a lime kiln depends on an efficient removal of (a) carbon monoxide, (b) steam, (c) oxygen, (d) carbon dioxide, (e) sodium.

6. When you blow into limewater the precipitate formed is (a) $CaSO_4$, (b) $Ca(OH)_2$, (c) $CaCO_3$, (d) CaO.
7. Quicklime is made by heating (a) CaO, (b) $CaSO_4$, (c) $CaHCO_3$, (d) $CaCO_3$.
8. The metal calcium is prepared by the electrolysis of fused (a) $CaSO_4$, (b) $CaCl_2$, (c) $Ca_3(PO_4)_2$, (d) CaO.
9. Bleaching powder is made by passing chlorine over (a) $CaCO_3$, (b) $Ca(OH)_2$, (c) Na_2CO_3, (d) $Ca_3(PO_4)_2$.
10. Permanent hard water can be softened with (a) zeolite, (b) soap, (c) sodium chloride, (d) boiling.

Complete and balance equations

1. $CaCO_3$ + heat ....
2. $CaCO_3 + H_2O + CO_2$ ....
3. $Ca(OH)_2 + H_2SO_4$ ....
4. $Ca(OH)_2 + HNO_3$ ....
5. $Ca(OH)_2 + CO_2 + H_2O$ ....

Additional

1. Explain the electrolytic process of getting Ca from its compounds and write equations for all reactions.
2. Explain how permanent hard water is softened and write equations involved.
3. Explain how bleaching powder is made and write out all equations involved.

General Science

APPARATUS

Quantity	*Article*	*Total Cost*
1 pkg.	Absorbent cotton (1/4 lb.)	$ .22
1	Air pump, vacuum and pressure	3.80
1	Air pump plate, with stopcock	6.50
6 ft.	Air pump tubing, 1/4 in.	1.14
12	Asbestos squares, 5 x 5	.18
3	Animal cages	24.00
1	Aquarium, 6 gal.	4.75
1	Aquarium, 2 gal., with glass cover	2.50
1	Balance, Cenco Trip, new design	8.55
		$51.64

Quantity	*Article*	*Total Cost*
1 set	Balance weights	$2.35
12	Balloons, rubber, small	.13
1	Barometer	5.00
1	Barometer tube, with pipet and well	.65
6	Beakers, pyrex, 400 c.	1.56
1	Bell jar, straight form, 1 gal.	3.25
12	Bottles, wide mouth, 16 oz.	.72
12	Bottles, wide mouth, 32 oz.	1.52
1	Ball and ring	.95
..	Bottles, 250 cc.	..
1	H_2SO_4—conc.	.60
1	HNO_3—conc.	.60
1	HCL—conc.	.60
1	NH_4OH	.60
12	Bottles, 125 cc.	4.15
12	Bottles, 250 cc.	5.10
3	Burner, Bunsen, 5/8 burner tube	1.71
2	Bar magnets, 15 cm. x 19 mm. x 6 mm.	.80
1	Bell jar	5.00
1	Bell jar	3.75
1	Bell jar, low form, open top	2.50
1	Battery substitute	13.00
1 box	Candles, Christmas (36)	.18
2	Clamps, right angle	.56
1 pkg.	Corks, assorted, Nos. 3 to 16	.72
1 set	Cork borers (set of 3)	.36
6	Crucibles, No. 1	1.68
1	Cylindrical vessel, 80 x 125 mm.	.45
1	Connection box	1.90
1	Compound bar	.45
1	Counter brush	.50
3	Clamp, buret, tubes up to 1 1/16″	1.20
1	Corkscrew, Alvert pick	.35
1	Compass	1.50
1	Demonstration balance (for fulcrum)	.52
		$64.91

Quantity	Article	Total Cost
6	Dry cells	$1.86
6	Dish, Petri, 100 mm. x 10 mm.	2.28
6	Dishes, 250 cc.	1.20
2	Electric bell, 2½ in. gong	.60
1	Emery cloth, Nos. 0, 00, 1	1.20
2	Electric buzzers, iron box	.80
2	Electrodes, carbon element, 2 x 12.5 cm.	.30
4	Electrodes, copper, gal. size	.20
6	Electrodes, zinc, gal. size	.30
2	Files, triangular, 5 in.	.18
1 pkg.	Filter paper, 11 cm. (100 circle)	.14
6	Flasks, Erlenmeyer, 125 cc.	2.50
1	First-aid kit	6.50
4	Funnels, fluted, 60° angle	.80
1	Glass model lift pump	1.35
1	Glass model force pump	1.35
5 lbs.	Glass tubing, 5 x 6 mm. assorted	2.45
6	Glass tumblers	.48
1	Heat conductivity apparatus	.45
6	Lamp chimneys, Argand	.78
1 sq. ft.	Lead sheets, 1/16 in. thick	1.25
1 set	Lenses, demonstration set	2.25
3	Lens holder	.36
12	Medicine droppers	.22
6	Meter sticks, maple	1.38
1	Microscope	60.00
72	Microscope slides, blanks, 25 x 75 mm.	.41
½ oz.	Cover slips, 22 mm.	.45
1	Pneumatic trough, enameled steel	.81
1	Prism, 75 x 28 mm.	.54
2	Push buttons	.28
1 sq. ft.	Rubber dam	.18
6	Rubber stoppers, 1-hole	.45
6	Rubber stoppers, 2-hole	.42
1 lb.	Rubber stoppers, assorted, Nos. 2 to 6	.58
		$95.30

Quantity	*Article*	*Total Cost*
12 ft.	Rubber tubing, $\frac{3}{16}$ in.	$ .96
12 ft.	Rubber tubing, $\frac{1}{4}$ in.	1.08
3	Ring stand	1.95
1	Rack, test tube	.50
4	Ring for ring stands, 4 in. with clamp	.88
1	Switch, single pole, single throw	.27
1	St. Louis motor	3.00
1	Sheets, copper, B & S No. 20	1.05
1	Screw driver, 6 in. slim	.30
1	Spatula, 6 in. blade	.50
2	Supports	1.70
3	Spring balances	1.50
24	Test tubes, 6 x $\frac{3}{4}$ in.	.50
24	Test tubes, 6 x 1 in.	1.00
3	Thermometers, double scale, 110° C. and 220° F.	3.15
12	Thistle tubes	1.08
1	Tuning fork, 256 vps.	1.25
1	Telegraph key	1.80
1	Telegraph sounder	2.25
6	Test tube holders	.30
2	Tongs, length 9 in.	.38
2	Tripod, iron for Bunsen burner, 5 in.	.66
1	Telephone receiver	1.80
1	Telephone transmitter	1.80
1	Tuning fork, adjustable unmounted	1.50
1 roll	Wire, Annunciator No. 20 (1 lb.)	.58
1 spl.	Wire, copper, DCC, No. 24 ($\frac{1}{4}$ lb.)	.45
4	Wire gauze, galvanized iron, 5 x 5-in. sq.	.48
4	Wire gauze, 5 x 5-in. sq., 16 mesh	.28
6	Brushes, test tube, bristled end, fan tip	.24
6	Glass tumblers, large 500 cc.	1.68
1	Humidiguide, Mason type	5.60
1	Knife, paring	.20
1	Lodestone	.20
		$40.87

Quantity	*Article*	*Total Cost*
1	Mechanics unit	$22.50
1	Magneto generator	6.85
6	Museum specimen jar, 8 oz.	.40
6	Museum specimen jar, 16 oz.	.66
2	Mortars, porcelain	.90
1	Meter stick support stand, with knife edge	.60
2	Magnets	.50
1 pair	Metal meter stick supports	.65
1	Mirror, concave and convex	4.75
2	Magnifiers	1.80
12	Needles, dissecting	.40
1 paper	Needles, darning, No. 5	.10
1	Pliers, gas	.30
1 lb.	Friction tape, ¾ in.	.80
6	Scalpels	2.10
		$296.03

SUPPLIES

1 lb.	Acid, boric, A.C.S. cryst.	$ .24
6 lb.	Acid, hydrochloric, C.P. sp. gr. 1.19–35% HCl	1.08
7 lb.	Acid, nitric, 1.40–68%–70% HNO_3	1.54
1 lb.	Acid, oxalic, cryst.	.35
9 lb.	Acid, sulfuric, 1.84–94% H_2SO_4	1.44
1 lb.	Acid, tartaric, cryst.	.70
½ lb. b.	Agar, nutrient, 1½%, dehydrated	.90
1 gal. tin	Alcohol, denatured	1.50
1 lb.	Aluminum and potassium sulfate crystals	.17
4 lb. b.	Ammonium hydroxide, U.S.P. 28%	.84
1 lb. tin	Calcium carbide tech. lumps	.30
1 lb. b.	Calcium oxide N.F. lumps	.25
1 lb. b.	Calcium sulfate, calcined, plaster of Paris, Tech.	.15
1 lb. c. b.	Carbon tetrachloride, C.P.	.30
1 oz.	Cobalt nitrate, cryst.	.40
1 bottle	Cement, label cement and varnish (11380A)	.75
		$10.89

Quantity	*Article*	*Total Cost*
1 box	Chloride of lime	$ .10
1 ball	Cord, white cotton	.10
1 lb. b.	Dextrose, U.S.P.	.44
1 lb. tin	Ether, U.S.P.	.44
1 lb. b.	Fehling's Solution A	.75
1 lb. b.	Fehling's Solution B	.75
5 lb. b.	Formaldehyde, U.S.P., 40% sol.	1.40
1 lb. b.	Glycerin, U.S.P.	.53
¼ lb.	Iodine, resublimed, U.S.P.	.73
5 lb.	Iron filings, fine, oil-free	1.00
1 quire	Litmus paper, blue, 8 x 10-in. sheets	.80
1 quire	Litmus paper, red, 8 x 10-in. sheets	.80
1 oz. roll	Magnesium, metal ribbon	.40
5 lb. ctn.	Manganese dioxide, Tech., powder	.80
5 lb. ctn.	Marble chips	.40
5 lb. b.	Mercury, redistilled U.S.P.	12.00
1 oz. b.	Methylene blue	.45
6	Natural fish food, 3-oz. jars	1.00
	Osmosis membrane, animal parchments sheets, 17 x 22 in.	.25
1 lb.	Paraffin "Parowax"	.20
¼ lb.	Phenolphthalein, U.S.P.	.20
5 lb.	Potassium chlorate, cryst., reagent A.C.S.	2.25
1 lb.	Potassium ferrocyanide, A.C.S. cryst.	1.35
1 lb.	Potassium permanganate, cryst. A.C.S.	1.65
1 lb. pkg.	Soap, Castile, pure, bars	.50
5 lb.	Sodium bicarbonate, powder, U.S.P.	1.65
1 lb.	Sodium carbonate, purified, crystals	.50
1 lb.	Sodium hydroxide, pellets, U.S.P.	.55
1 lb.	Sodium potassium tartrate, cryst., U.S.P.	.55
2 pt. tin	Sodium silicate, solution, 40° to 42°	.35
1 lb.	Sodium thiosulfate, C.P. cryst.	.50
1 lb.	Soluble starch powder	1.45
1 lb.	Strontium nitrate, purified, granular	.10
5 lb. ctn.	Sulfur, sublimed, U.S.P.X.	.60
		$36.46

Quantity	*Article*	*Total Cost*
1 lb. pkg.	Tin, metal, pure, foil 0.0015-in. thick......	$1.80
1 lb.	Zinc dust	.80
1 pkg.	Borax	.25
	Pins, insect, Klaeger No. 3 with brass head..	.50
1	Petrolatum, carbolated, screw top, 4-oz. jar.	.22
3	Wax pencils, Blaisdell, glass marking, blue.	.45
3	Wax pencils, Blaisdell, glass marking, red..	.45
10 lb. bag	Fertilizer, Vigoro	.50
		$ 52.42
	Supply total	$ 52.42
	Apparatus total	296.03
	Complete total	$348.45

Equipment and supply lists for chemistry, physics, and biology may be procured from scientific supply firms.

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